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HHFA-USPHS HOUSEHOLD SEWAGE DISPOSAL PROJECT

REPORT AND APPENDIXES

PUBLIC HEALTH SERVICE, CINCINNATI, OHIO

JANUARY 1948

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SECOND PROGRESS REPORT

of

HHFA-USPHS HOUSEHOLD SEWAGE DISPOSAL PROJECT

January, 1948

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January, 1948

U. S. Public Health Service
Sanitary Engineering Division
Water and Sanitation Investigations
Cincinnati, 2, Ohio

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REPORT

INTRODUCTION

The Second Progress Report of the H.H.F.A.-U.S.P.H.S. Household Sewage Disposal Project which follows, covers primarily the developments since the First Progress Report, August 1, 1947, and is interded to be used in conjunction with that Report. Where it has been considered useful for purposes of clarity and convenience in comparing earlier results with those developed during this period the previous data have been repeated or otherwise taken into account in the analysis of various factors.

The Authorization and Objectives were presented in the First Report and are not repeated here. The form of this Report is identical to that of the First i.e. a report of progress on the 18 objective items individually.

The project reached a peak in personnel employed in September 1947 with a staff of 30. Considerable of a turnover in personnel developed during the progress of the study a total of 47 persons being taken on at one time or another. This does not include the part time assignment of personnel from the Cincinnati Station Staff in connection with administrative and fiscal activities.

At a meeting of the informal advisory committee October 22, 1947, at which time the immediate future of the project with respect to funds available was discussed, it was decided to cut back on the field and laboratory personnel sufficiently to avoid suspension of the project in April, and possible loss of key personnel necessary to complete unfinished work and carry on various phases requiring extended study, should funds for continuing the work become available for the next fiscal year. The consequent reduction in forces is reflected in the table following, which indicates the personnel complement of the project by months since its start.

Number and Distribution of Personnel *

Month	On loan from Station Staff (Salaries paid by P.H.S.			Project Staff (Salaries from H.H.F.A. Fund)			
	Tech.	Labor	Total	Tech.	Cler.	Labor	Total
Dec., 1946	2	-	2	-	-	-	-
Jan., 1947	6	1	7	1	1	-	2
Feb.	4	1	5	7	1	2	10
Mar.	3	1	4	7	1	3	11
Apr.	2	-	2	8	1	3	12
May	2	-	2	10	1	5	16
June	2	-	2	13	1	9	23
July	2	-	2	13	1	10	24
Aug.	2	-	2	13	1	10	24
Sept.	2	-	2	14	1	13	28
Oct.	2	1	3	13	1	11	25
Nov.	2	-	2	12	1	7	20
Dec.	2	-	2	8	1	4	13
Jan. 1948	3	-	3	5	1	3	10
Person months (whole or part)	36	4	40	125	13	80	218

* Exclusive of part time services of Station administrative and fiscal personnel.

As of the end of January, 1948 the H.H.F.A.-U.S.P.H.S. Project was staffed and assigned as follows, the project being handled as one major activity of the Cincinnati Station under the administrative direction of Sanitary Engineer Director H. W. Streeter, Officer in Charge, Water and Sanitation Investigations:

H.H.F.A.-U.S.P.H.S. Project Staff

Name	Title and Grade		Assignment
	Engineering - 5		
Weibel, S. R.	Sr. P.H. Engr.	P-5	In charge of project
*Straub, C.P.	San. Engr.		Conduct research program
*Thoman, J.R.	S. A. San. Engr.		Central office, review lit., analysis data.
Hamblett, W.	P. H. Engr.	P-3	Research
Longan, F. E.	P. H. Engr.	P-1	Field Surveys

* On loan from Cincinnati Station Staff.

Scientific - 3

*Clark, H.F.	Chemist	P-3	Research
Cohen, J.	Chemist	P-2	"
Pruden, C. C.	Lab. Aide	SP-4	"

* Formerly assigned full time; presently on part-time loan from Cincinnati Station Staff.

Clerical - 1

Guethlein, M.L.	Clerk Typist	CAF-3	Central office.

Labor - 3

Stephenson, C. G.	Skilled Laborer	CPC-4	Cincinnati
Cholak, L. S.	" "	CPC-4	"
Rudolf, E.	" "	CPC-4	"

Grateful acknowledgement is made of the assistance given the project by representatives of the Housing and Home Finance Agency, Federal Housing Administration and Public Housing Administration, the Public Health Service Sanitary Engineering Division, and the Cincinnati Station Staff in guidance given at the several conferences and various aids in particulars too numerous to outline; the Public Health Service District Offices for liaison in connection with the opening of field study areas, for providing desk space, transportation and assistance in hiring field labor; the State, County and Municipal Health Departments cooperating in the areas in which study has been or is now being made and those also who offered similar cooperation in their respective areas; the manufacturers of tanks, appurtenances and equipment who made special efforts to expedite delivery of purchases for the project; the universities, engineering schools, agricultural colleges, extension and experiment stations, libraries, individual scientists in the United States and foreign countries, and manufacturers who willingly responded to requests in connection with the review of literature; and finally, the staff of the project, which has undertaken assignments, some of which are far from pleasant, with willingness and purpose seldom obtained in a necessarily hastily organized temporary staff.

1. Collection and analysis of existing data

A. Review existing publications and unpublished studies both domestic and foreign, regulations, and commercial brochures on the design, capacity, durability of construction materials and operating results of septic tanks and disposal systems and indicate such publications that offer information on acceptable principles to be followed.

Some additional references have been obtained for the literature survey since the First Progress Report, and these additions to the bibliography presented in Appendix A of the August report are listed in Appendix A of this report. Additional information is mainly from foreign sources, most of whom were contacted prior to the first report. However, since then contacts have been made with individuals in Sweden, Chile, Italy, Norway, Argentina, Bolivia, Cuba, and Spain. Response from this group has been poor, however. In the following sections additional history is presented, and summaries of practice in several foreign countries or additions to previously reported information is given. Summaries of practice in the various States relative to building sewers, cesspools, and seepage pits are presented, and the complete tabulations are presented in Appendix A. An estimate of the total number of septic tanks in the United States is given. Information is also presented relative to the quantities of water used with automatic washing machines.

History

The discovery of the household septic tank is generally credited to John Louis Mouras, who during the 1860's constructed a masonry tank in which sewage, kitchen wastes, and rain water from a small dwelling located in Vesoul, France were collected before passing to a cesspool. Twelve years later the tank was opened, and found, contrary to expectations, to be almost free of solids. As a result a series of experiments were made in collaboration with a priest, Abbe Moigno, editor of Cosmos les Mondes and a scientific authority of his time. The satisfactory completion of these experiments induced Mouras to patent his invention on September 2, 1881.

The experiments conducted by Mouras and Moigno consisted of the operation of a small, sealed tank with glass sides for observation of the phenomena occurring within the tank. Urine, fecal matter, and a small amount of water were added daily in one experiment, and Moigno stated that "introduced the 29th of August, the solid excretions were completely liquified by the 16th of September with the exception of materials not digested by the stomach....." A sample of the tank effluent showed little turbidity and when diluted 1:10 with water had only a slight odor. The movement of particles within the tank from top to bottom, and conversely, was described, and an attempt made to determine if gas was generated by the process. Moigno claimed that no gases were given off when the tank was heremetically sealed, but that when air was permitted to enter the tank "... malodorous gas bubbles began to form, and increased with time". Finally, he concluded that liquefaction of the suspended material appeared more active when more water was used for flushing.

In the United States, it appears that the use of the household septic tank dates back to about 1883, when a two chamber, round, vertical tank, equipped with a dosing siphon for the discharge of the effluent (Appendix B, First Progress Report), was designed by Edward S. Philbrick of Boston, Massachusetts.

The septic tank as a distinct process of sewage treatment was introduced in England by Cameron in 1895. Patents were obtained by Cameron both in England and the United States, and litigation resulting from alleged infringements developed in this country. A complete reveiw of the situation was made by Leonard Metcalf in the 1901 Transactions of the American Society of Civil Engineers. Metcalf concluded that the individual functions inherent in the septic process were developed and used long before the process was patented by Cameron.

Ecuador

The Direccion General De Sanidad, Republic of Ecuador, recommends the use of a single compartment rectangular septic tank for from 1 to 10 persons. The tank is 1.4 m. long, 0.7 m. wide, and 1.2 m. water depth with a freeboard of 12 in. It has a tee inlet to 18 in. below the water surface, and a tee outlet to 12 in. below.

For effluent disposal three methods are given; disposal to a river or estuary; filtration through a subsurface tile field; or, disposal through a system of seepage pits. The tile field is made up of 4 in. diameter concrete or vitrified clay pipes, 1 ft. long, laid with a grade of 3-4 in. per 100 ft. The following amounts of tile are specified.

Porous soil - 20 m.
Medium soil - 30 m.
Clayey soil - 50 m.

No recommendations are given as to the size or capacity of seepage pits, nor is the use of such a system qualified. The use of effluent discharge to a stream is not recommended where contamination of a domestic water supply would result.

Dominican Republic

The septic tank recommended by the health department of the Dominican Republic to serve 10 persons has the following characteristics.

2 compartment rectangular
Length - 1st - 1.3 m.
2nd - 0.7 m.
Width - 0.9 m.
Water depth - 0.9 m.
Freeboard - 0.3 m.

The inlet is an elbow and the outlet a tee. No details are available concerning disposal systems.

Venezuela

The health authorities of Venezuela specify a single compartment rectangular tank of sufficient capacity to afford a detention period of 24 hours. The minimum size tank (to serve 1 to 4 persons) has a capacity of 1300 liters and the following dimensions: Length - 1.3 m., width - 1.0 m., water depth - 1.0 m., Freeboard - 0.3 m. The tank is equipped with tee inlet and outlet.

For effluent disposal the use of seepage pits of sufficient capacity is recommended. No specific recommendations are given, however, consideration of the soil permeability and local conditions is advised. The use of seepage pits in areas served by shallow wells is prohibited.

Poland

According to Skrobecki writing in a recent issue of a Polish journal, the "Ems" type settling tank has found satisfactory use in Poland. This type of tank is a modified Imhoff tank similar to the fresh-water clarification tanks used in Germany during the 1920's. Usually built in round form, the flowing - through chamber is located above the digestion chamber and connected by means of a narrow slot.

The settling chamber has a capacity equal to 20-25% of the daily wastes with a minimum of 0.5 cu. meter or 147 gallons. The surface area in square meters should be numerically equal to the volumetric capacity in cubic meters. Between 0.07 and 0.1 cu. meter digestion space is provided per person with a minimum of 1 cu. m. (35.3 cu. ft.).

Skrobecki states that cleaning of these tanks should be done every six months, but that in practice it is usually one or two years. The tanks are usually built of precast concrete rings 1.1 m. in diameter.

United States - State Requirements

Three tables are presented in Appendix A which are a continuation of the tabulation of the State Requirements for household sewage disposal systems originally presented in the August report. These compilations cover State requirements concerning the house sewers, seepage pits, and cesspools. For those States where no information is given, either the bulletins were not available or the reference at hand did not cover the particular subject.

House Sewer

Table 1A gives information contained in State requirements concerning house sewers. In general a tight sewer of adequate size with sufficient grade to prevent stagnation is required. The minimum diameter pipe used is 4 in. with several States requiring the use of 6 in. pipe. Fifteen States require the use of cast iron pipe when the sewer is in the proximity of a well. The distances within which this type of pipe must be used vary from 25 to 100 ft., with the usual practice being 50 ft.

Minimum grades recommended vary from 0.5 to 2.0 ft. per 100 ft. The most common practice is to use a grade of 1%. Recommendations concerning approved jointing materials vary quite widely, however, in ordinary circumstances most States allow the use of mortared joints. Several States call particular attention to the protection of joints to entrance by roots. Materials used for this protection were discussed more fully in the August Report.

Seepage Pits

Data available from the States concerning the use of seepage pits as a means of septic tank effluent disposal are given in Table 2A. Of 32 States making recommendations concerning seepage pits, only 4 prohibit their use. The others recommend the use of pits of various designs and construction for a variety of conditions. Some States require that the pit be of certain size, while others base the design on the absorption area required as shown by a percolation test. Several require that the pit extend into a porous formation. One State does not approve the use of seepage pits unless tile field systems are not suitable, while several recommend that a pit be used at the end of the tile lines. One State does not allow the use of seepage pits unless the lot area exceeds ½ acre. This is the only case where a minimum size lot is required.

Four States recommend the use of the percolation test for designing seepage pits, and a comparison of these data show that no two are the same, though they are in general agreement. Five States make recommendations as to absorption area required based on the type soil encountered. These, too, show considerable variance between States.

Twenty States specify certain minimum distances between seepage pits and water supplies, streams, dwellings or property lines. The usual distance from a water supply is 100 ft, though the individual recommendations vary from 30 to 300 ft. Other recommendations vary widely, and only a few States present specifications for all conditions listed above.

Cesspools

Table 3A presents the data available from State sources concerning cesspools. Requirements are given by 19 States, and of these, cesspools are allowed in 12, and prohibited in 7. However, of those States allowing the use of cesspools one requires that they are to be used for floor waste only, another for laundry waste only, and another for kitchen and laundry only. Practically all of the States allowing their use qualify the requirements, and, in general, the use of a cesspool is not recommended as the desirable system of sewage disposal. In some states where the use of cesspools is prohibited, the Codes governing disposal facilities specifically state that cesspools shall not be used.

Percolation Test

Since the last report information has been received which outlines the procedure used by the late Henry Ryon in the development of the soil percolation test for determining tile absorption field requirements. In addition a chart was obtained which shows the individual cases used in deriving the general requirements. This material is presented later in the report in the section analyzing the field inspection data, and hence is not repeated here.

Number of Septic Tanks in the United States

No accurate estimate of the total number of septic tanks in the United States exists, nor do any data exist which will furnish this information in a straightforward manner. The methods which have been used in preparing this present estimate, are based on the use of data which in itself is an estimate, and should be reviewed in that light. However, no other method of obtaining any reliable figure was found.

According to this method of estimation there are approximately 4,400,000 septic tanks in the United States. The 1944 National Inventory of Sanitation Needs was used for supplying the necessary data, and all information is from this report.

1. Population for which extensions to existing sewer system are needed

   10,297,300 - approx. 2,574,300 dwellings

2. Population for which new sewer systems are needed

   4,835,847 - approx. 1,208,900 dwellings

3. Rural dwelling units in U. S.		12,971,360
Outside toilet or privy	8,505,572	
No toilet or privy	846,148	
	9,351,720	9,351,720
Units with some other disposal		3,619,640

1. Assume 80% of units in Class I	2,000,000
2. Assume 50% of units in Class II	600,000
3. Assume 50% of units in Class III	1,800,000
	4,400,000

Class I includes the population in incorporated communities of over 200 pop. which need extensions to sewer systems. According to the 1944 Inventory only those actually needing extensions are reported. It may be assumed that a large percentage of the homes in these areas are equipped with running water and flush toilets, since sewers need only extension, and hence in planning for such future work would probably be equipped with septic tanks or some type of water-carriage sewage disposal.

Class II includes the population in incorporated communities of over 200 pop. for which new sewer systems are needed. In this case it might be expected that privies are in widespread use, hence it was assumed that only 50% of the homes in this category are equipped with septic tanks.

Class III includes rural homes from a different standpoint than that usually employed by the Census Bureau. It includes all homes in the Rural-Farm classification, and those Rural-Nonfarm homes outside of incorporated communities. The total figure includes dwellings equipped with septic tanks or other disposal methods (to storm drains, ditches, cesspools, etc.), and also those units having non-flush toilets in the house. This latter item is probably less than 1% of the total units involved, and has not been considered. Since the dwellings equipped with privies are not included in this figure, it seems reasonable to assume that 50% of the units in this class are equipped with septic tanks.

Water consumption - Automatic washing machines

Several questions have been raised concerning the effects on septic tank operation of the increased use of automatic washing machines. Factors which must be considered include the increased use of water with this type of machine, and the rates of discharge of the pumps to the drain.

To obtain information pertaining to this problem, companies manufacturing this type of equipment were contacted for specific details regarding their product. The information received is summarized in Table 1.

To compare the water usage under average conditions, a four load wash was assumed, rather than a specific weight of clothes, since it represents usual washing procedure regardless of the total weight of clothes. The water quantities used for four loads, and the percentage use in relation to that used in a wringer type machine are given in Table 2.

For the fully automatic type of machine the water usages vary from 96 to 224 gallons for a four load wash as compared with 58 gallons used with a wringer type machine. The percentages expressed in terms of a wringer type machine vary from 166 to 386. With a minimum installation of 4 persons and an assumed flow of 50 gcd, the water used by these automatic machines will vary from approximately 50 to over 110% of the total daily sewage quantity.

It is evident from these data that serious consideration in designing septic tanks must be given to allowances for increased water usages with the automatic type washing machines. It is planned to further analyze these data with respect to actual flow conditions as determined with the field sampling and gauging equipment.

One factor in the use of automatic washers which may tend to modify the effects of the increased water consumption is the tendency to do the washing at different times during the week rather than the entire washing at one time. With the spinner and wringer type machines it is necessary to do all the washing at one time, if the economies inherent in these type machines are to

Table 1. Automatic Washing Machines - Manufacturers Rated Water Consumption

Trade Name & Mfg.	Wt. Clothes per Cycle (lb.)	Soak (gal.)	Wash (gal.)	Rinse (gal.)	Rinse (gal.)	Total (gal.)	Time of Cycle (min.)	Max. Disch. of Pump (gpm)	
"Launderall" F.L. Jacobs Co. Detroit, Michigan	10	-	9	8	8	25	40	3.8 - 4.2	
"Thor Automagic" Thor Corporation Chicago, Illinois	8	-	11	30-45	-	41-56	25-30	11-14	
"Blackstone" Blackstone Corp. Jamestown, N. Y.	8	-	14	26-31	-	40-45	25-38	15	
"General Electric" General Electric Co.	9	17	20	20	-	57	20-37	12	Rinse water can be saved for soak
"Laundromat" Westinghouse Electric Corp.	9	-	9.7	4.0	9.3	23	31.5	12	
"Bendix" Bendix Home Appliances, Inc. South Bend, Indiana	9	7.3	5.4	9.6	6.6	28.9		6.5 - 8.7	

be realized. With the automatic type machine, no economy is realized by doing the washing on one day with but one exception where it is possible to save the last rinse water for use as the soak for the next load. Therefore it is possible that the wash water load will be spread over a longer period of time than with the wringer or spinner type machines.

Table 2 Washing Machines - Water Consumption

Hypothetical Four - load Wash.

	Water used for 4 loads - gal.	% of water use in wringer type
Launderall	100	172
Thor Automagic	164-224	283-386
Blackstone	160-180	276-311
General Electric	177	305
Laundromat	96	166
Bendix	115.6	199
Easy Spindrier	70	121
Wringer type*	58	100

*based on 2 tub rinse of 14 gal. each plus first rinse replacement.

2. Investigate existing installations of different sizes, shapes, types, and materials, and determine efficiency of sedimentation, durability of materials, adequacy of sludge storage, and other basic characteristics.

The number of inspection teams in the field reached a peak of 6 in June, was reduced to 5 in July with the assignment of one of the engineers to sampling and gaging, to 4 in September through resignation, and to 2 and 1 in November and December respectively, through reduction in personnel due to budget circumstances.

More rapid progress was evidenced in the field as a whole beyond July due to increased experience on the part of the field men, development of more fruitful areas and the revision of procedures to make one complete tank and disposal field examination to every four examinations of tanks only on the average. The number of inspections per month reached a high of 50 during August.

Distribution of Inspections - The following four tables present the distribution of septic tank inspections through December 15, 1947 by areas, tank types, years in service or years since last cleaning, and by plumbing fixtures connected to the septic tank system.

Table 3 gives the distribution of inspections by areas.

Table 3. Distribution of Inspections by Area

Area No.	Location	Total Inspections through December 15, 1947
1	Dallas	15
2	Kansas City	92
3	Cook County, Illinois	45
4	St. Joseph County, Indiana	34
5	Cincinnati	42
6	Kalamazoo	10
7	Warwick County, Virginia	34
8	Cuyahoga County, Ohio	-
9	Montgomery County, Alabama	-
	Total	272

Area No. 8, Cuyahoga County, Ohio, was a special detail to investigate garbage grinder-septic tank installations. Due to several factors, no surveys were completed. Area No. 9 was opened during December, and no inspections were received by December 15th.

The distribution of inspections by tank types is shown in Table 4.

Table 4. Distribution of Inspections by Tank Type

Tank Type	Conc.	Tile	Steel	Brick	Conc.Blk.	Stone	Total
Single vert. cyl.	1	-	60	6	1	1	69
Double " "	7	6	-	2	-	-	15
Triple " "	4	-	-	-	-	-	4
2 Comp. single vert. cyl.	1	-	-	-	-	-	1
3 " " " "	1	-	-	-	-	-	1
Total	14	6	60	8	1	1	90
Single hor. cyl.	1	1	-	-	-	-	2
3 comp. " "	-	3	-	-	-	-	3
Total	1	4	-	-	-	-	5
Single comp. rect.	98	-	-	16	5	-	119
Double comp. rect.	14	-	-	10	-	1	25
Triple " "	11	-	-	20	1	-	32
Quad. " "	-	-	-	-	-	1	1
Total	123	-	-	46	6	2	177
Grand Totals	138	10	60	54	7	3	272

Approximately two-thirds of the inspections were made on rectangular tanks. During the latter part of the survey, the inspection of round vertical steel tanks was discouraged due to the poor structural condition of a great number of those previously inspected, which resulted in non-use of the data for sludge and scum accumulation.

The distribution of tanks by years in service is given for 189 dwellings in Table 5. Early in October the field men were instructed to attempt to inspect tanks which had been in service longer than 5 years to fill out the available data for the longer period. The field team in Warwick County was able to satisfy this criterion, and furnished a number of reports which aided materially in filling out the data for sludge and scum accumulations for 6 to 9 years service.

Table 5 Distribution of Tanks by Years of Service

Years	No. Insp.	Years	No. Insp.
0.5	4	9	13
0.75	4	10	1
1	13	11	4
1.5	2	12	4
2	14	13	4
2.5	2	16	1
3	23	20	3
3.5	2	21	1
4	12	24	1
5	16	32	1
6	28	33	1
7	15	39	1
8	19	Total	189

The distribution of wastes at 263 installations is shown in Table 6. The performance of laundry in the home is also shown in this table for 258 inspections.

Table 6. Waste distribution at field installations

Wastes to Septic Tank	Distribution by Areas							Total	
	1	2	3	4	5	6	7	No.	%
Bathroom, kitchen, laundry	5	15	12	17	17	2	15	83	32
Bathroom, kitchen	9	42	7	9	12	4	10	93	35
Bathroom, laundry	0	2	4	0	0	0	0	6	2
Bathroom only	2	27	21	8	10	4	9	81	31
Total	16	86	44	34	39	10	34	263	100
Laundry not done at home	11	13	4	12	4	4	7	55	21
Laundry done at home	5	71	40	20	35	5	27	203	79

Kitchen and laundry wastes not discharged through the septic tank were either passed by the tank to the disposal system, to a separate tile system, or to a surface watercourse in a few cases. Field men were instructed at the July 18th conference in Kansas City to select systems in which all wastes were discharged to the septic tank. From later field reports submitted, it appears that it was not possible to comply with this directive, the systems receiving all wastes occurring about once in every three cases. In discussions with health authorities in one Southern state having close control over septic tank installations over a long period of years, it was brought out that the location of the drains from the various fixtures determined if all wastes were discharged to the tank or if only part went into the tank. In Warwick County where close supervision of septic tank installations is exercised, only 44% of the installations inspected received all the wastes, and 26% received only bathroom wastes.

Bedroom Loading and Water Use - The number of persons per bedroom at 264 dwellings where tanks were examined averaged approximately 1.7 persons per bedroom. The distribution is shown in the following table.

Table 7. Resident persons per bedroom

No. of Bedrooms	Resident Persons 1	2	3	4	5	6	7	8	9	Total
1	1	7	1	-	-	-	-	-	-	9
2	1	30	57	41	16	1	1	1	-	148
3	1	2	12	39	12	9	2	-	-	77
4	-	1	2	5	6	5	1	-	1	21
5	-	-	1	-	1	2	3	-	-	7
6	-	-	-	-	-	1	1	-	-	2
Total	3	40	73	85	35	18	8	1	1	264

Cases to the right of the heavy line indicate homes in which bedrooms were used for more than two persons per room. In its design criteria, the Joint Committee used the maximum probable use of the house based on occupancy of two persons per bedroom. This method of application of the population design factor is more expressive of conditions as they might actually exist in the future, whereas designing strictly on present occupancy tends to ignore possible future increases in the population of the house.

In the 264 houses listed in this tabulation, 23, or 9% were populated with more than 2 persons per bedroom, 57, or approximately 22%, were being used at the loading of 2 persons per bedroom; and the remaining 69% at a loading of less than 2 persons per bedroom.

Water use data for Summer and Winter conditions were collected from 150 dwellings having metered water supplies at which inspections were made. The per capita water use by resident persons is shown in the following table.

Table 8. Water Use - gallons per capita per day

Resident Persons (1)	No. Dwlgs. (2)	Summer Mean (3)	Summer Med. (4)	Summer Max. (5)	Summer Min. (6)	Winter Mean (7)	Winter Med. (8)	Winter Max. (9)	Winter Min. (10)
1	1	58	-	-	-	50	-	-	-
2	25	75	62	226	16	52	48	100	8
3	39	44	42	80	14	39	34	83	12
4	49	38	38	77	8	33	32	85	12
5	21	41	34	170	15	35	30	150	13
6	8	38	29	109	20	30	24	77	15
7	5	37	-	-	-	28	-	-	-
8	1	32	-	-	-	22	-	-	-
9	1	23	-	-	-	23	-	-	-
Total	150								
Av.		46				38			

The average per capita water use was 46 gallons in the Summer months, and 38 gallons in the Winter months. It appears from an examination of the data from 2 to 7 years, inclusive, that there is a decrease in water usage as the resident persons in a dwelling increases. This confirms the statement originally proposed in the August Progress Report.

Sludge and Scum Accumulation

In the following sections an analysis of the accumulation of sludge and scum in septic tanks inspected in the field is made. In preparing the data for these analyses, inspection reports were carefully selected so as to eliminate those which did not fit certain primary considerations. The following criteria were used in selecting reports.

1. Accurate and definite history must exist.
2. The tank must not be full of sludge and scum.
3. The outlet device must be intact, so that scum cannot pass to the disposal system.

It was necessary that each report meet these criteria, so that the data presented would meet the stated limitations, and not be subject to additional question.

No attempt was made to break down the accumulations by tank types, capacities, loadings, sizes, or waste arrangements due to the paucity of data available for use in each individual class. Instead of an analysis by this method, comparisons with the mean curve developed, using all available reports regardless of individual classification, have been made. These are presented in later sections after the presentation of the main accumulation curve for all tanks.

The fact that the mean accumulations are not prepared on the basis of the various classes, should be borne in mind when reviewing all analyses where these points are used. For a strict interpretation of the data, the sludge and scum accumulations should be broken down by tank classes. However, this is not possible due to the small amount of data within each class.

Table 9 lists all the data available from the field inspection reports concerning the accumulation of sludge and scum. Mean and median rates for scum and sludge individually and for the total are presented, as well as the mean total quantity, which is the mean rate multiplied by the number of years. Fig. 1 shows the plot of the mean points. In addition, the number of inspections taken into account in arriving at the mean are listed, as well as the mean capacity per person of the tanks involved in each yearly point. Figs. 2 and 3 show the curves developed from the mean and median rates of accumulation, and the scum component of these curves. In plotting these curves, only the points representing years 1 to 9, inclusive, were used, with the fractional years omitted. The few number of inspections in the other yearly groups precluded their use in preparing these curves. This compilation of data represents the available materials concerning scum and sludge accumulation. An analysis of the individual items follows.

Table 9. Rate of Accumulation of Sludge and Scum by Years of Service

Years	No. Insp.	Mean Rate			Median Rate			Mean Quantity
		Scum	Sludge	Total	Scum	Sludge	Total	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0.5	4	2.32	9.55	11.87	-	-	-	-
0.75	4	0.13	4.29	4.42	-	-	-	-
1	13	0.69	2.44	3.13	0.27	2.17	3.02	3.13
1.5	2	1.75	1.13	2.88	-	-	-	-
2	14	0.58	1.82	2.40	0.39	1.72	2.39	4.80
2.5	2	0.61	1.04	1.65	-	-	-	-
3	23	0.58	1.55	2.13	0.35	1.12	1.63	6.39
3.5	2	0.27	0.50	0.77	-	-	-	-
4	12	0.38	1.89	2.27	0.39	1.91	2.18	9.08
5	16	0.36	1.08	1.44	0.26	1.07	1.31	7.20
6	28	0.41	1.05	1.46	0.41	0.90	1.39	9.76
7	15	0.42	1.29	1.71	0.40	1.19	1.74	11.97
8	19	0.43	0.90	1.33	0.32	0.98	1.41	10.64
9	13	0.50	0.87	1.37	0.41	0.79	1.28	12.33
10	1	0.22	0.99	1.21	-	-	-	12.10
11	4	0.65	0.82	1.47	-	-	-	16.17
12	4	0.23	1.10	1.33	-	-	-	15.96
13	4	0.48	0.89	1.37	-	-	-	18.84
16	1	0.26	0.46	0.72	-	-	-	11.52
20	3	0.24	0.94	1.18	-	-	-	23.60
21	1	0.02	0.82	0.84	-	-	-	17.64
24	1	1.12	2.75	3.87	-	-	-	-
32	1	0.33	0.71	1.04	-	-	-	-
33	1	0.35	0.56	0.91	-	-	-	-
39	1	0.05	0.21	0.26	-	-	-	-

The trend of Curve No. 1 of Fig. 1 is downward, and is demonstrated more clearly in Fig. 2. However, the points used to draw the curve do not follow as closely as might be desired, and indicate that some explanation be made. From an initial examination of a few selected points it was apparent that the sharp humps

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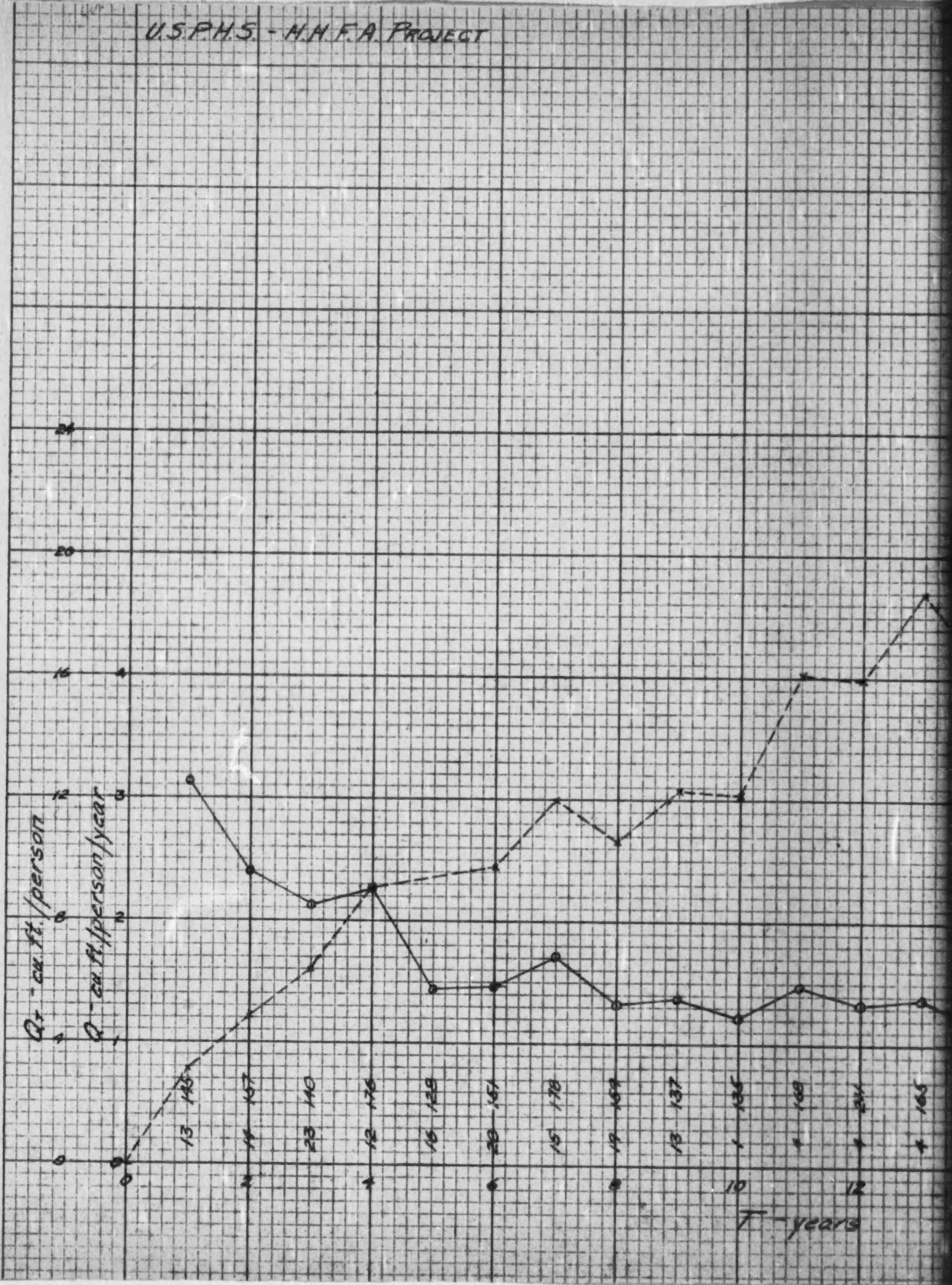
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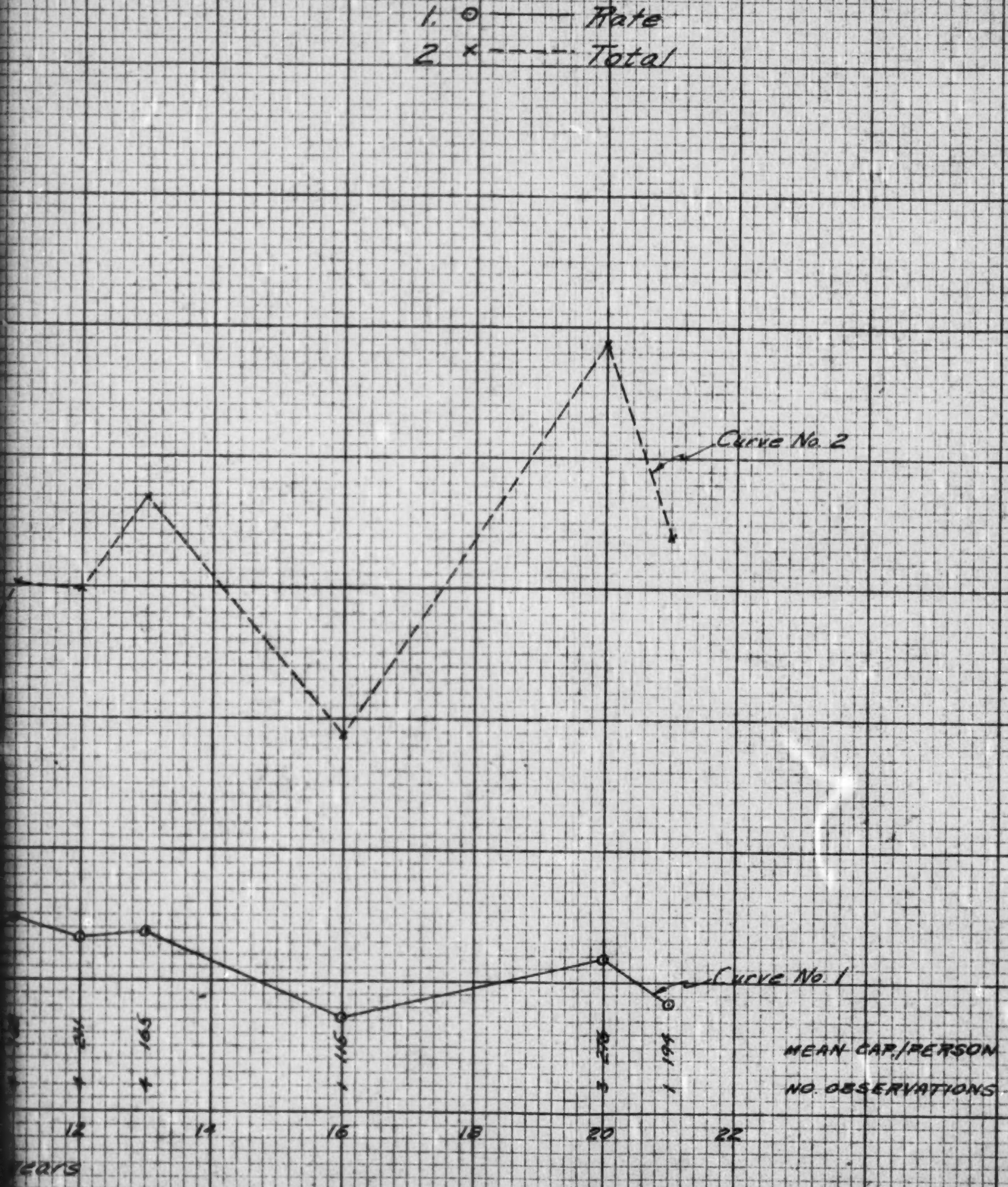
DECEMBER 1947

Fig. 1 - Mean Scum & Sludge Accumulation



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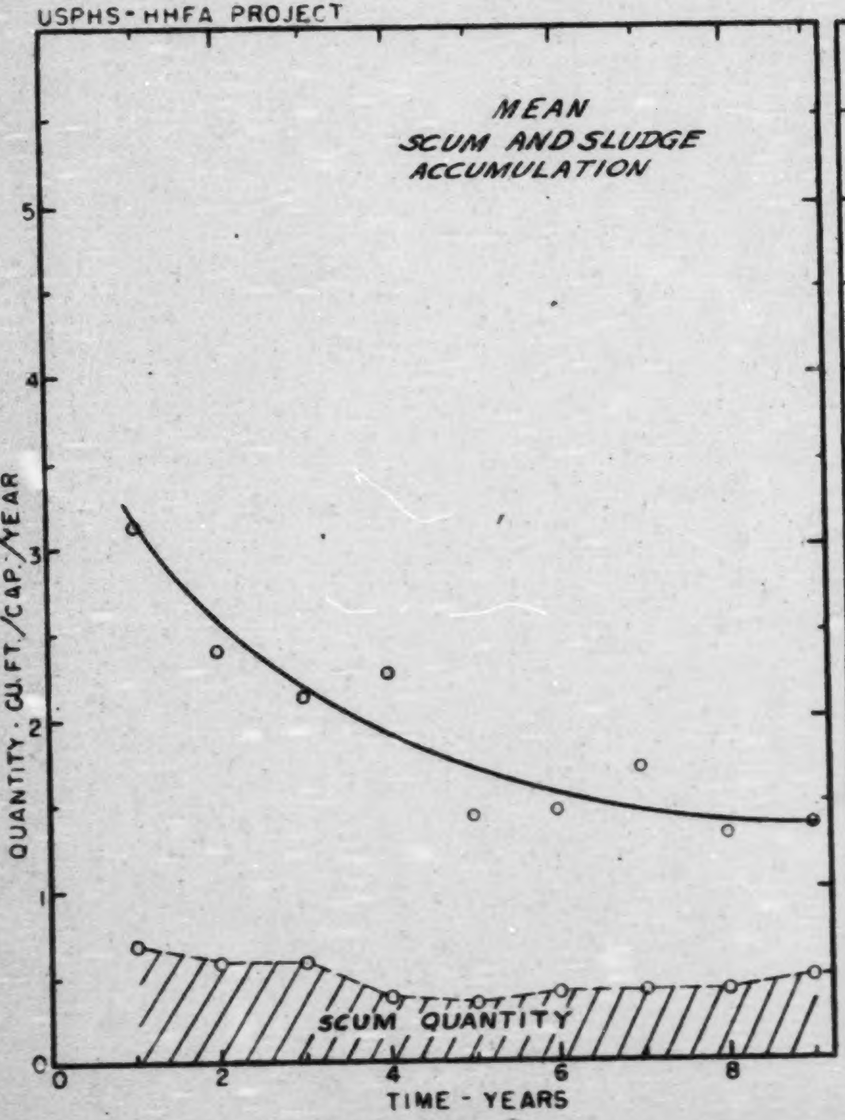

FIG. 2

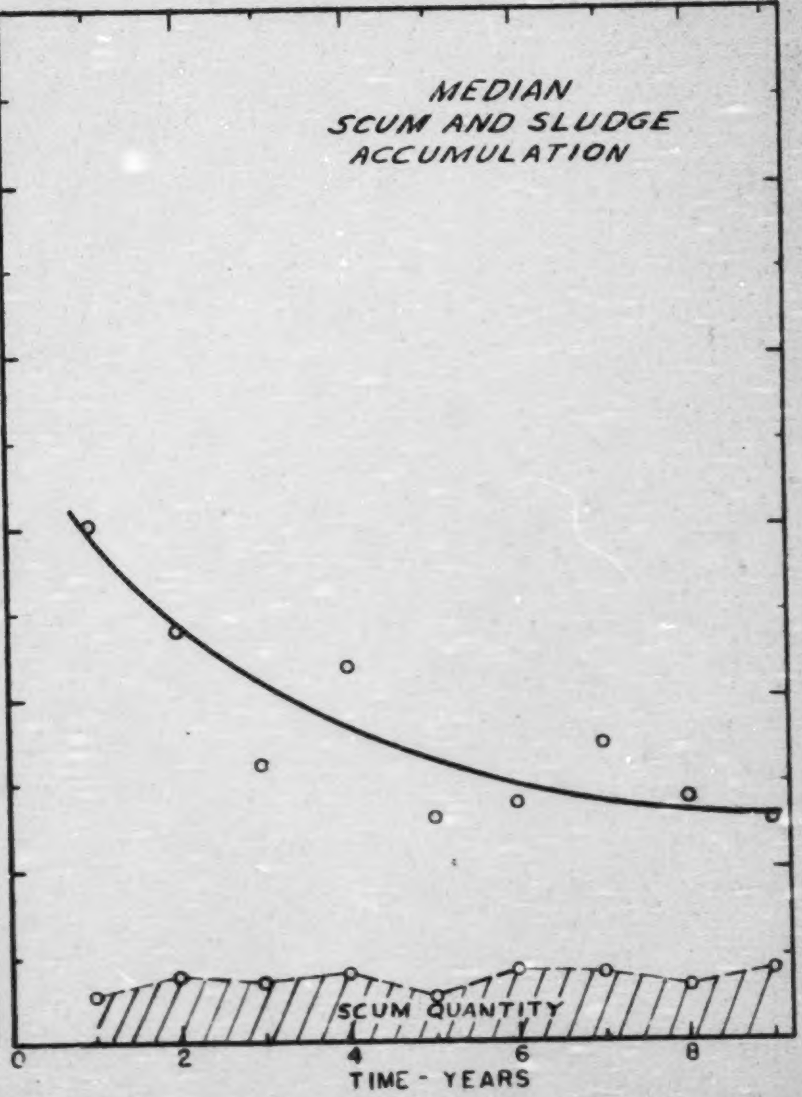

FIG. 3

and depressions were probably due to differences in the per capita tank capacities. This point was borne out when a closer analysis was made. For the period of 1 to 9 years, the mean capacity per person of all tanks is 151 gallons. By comparing this with the mean capacities shown on Fig. 1, the causes for the divergence of the points from the mean curve become apparent. An attempt has been made to correct the individual accumulation values by proportion with the capacities. The results of this computation are shown in Fig. 4. A much better fit of points is obtained and the large differences at 4 and 7 years are minimized. It is planned to attempt adjustment of this data by other means, however.

Compared with the change in total rate of accumulation of scum and sludge, the rate of accumulation of the scum component is very slight. In Fig. 2, it is shown that the mean rate of scum accumulation is quite constant after 4 years, and that it varies but little over the entire range of 9 years.

Sludge and Scum Accumulation by Tank Capacities

In Figs. 5, 6, 7 and 8 are shown a breakdown of sludge and scum accumulation for individual tanks on the basis of per capita tank capacity. It is demonstrated from an inspection of these graphs that when the per capita tank capacity exceeds 175 gallons, the sludge and scum accumulation rates exceed the mean. Thus, using the criterion that the most efficient tank is the one accumulating the most sludge and scum, it appears that a minimum capacity of 175 gallons per person would be necessary.

It should be borne in mind, however, that all tanks were considered in preparing the mean curves, and that the criterion employed assumes that digestion is proceeding at the same rate in all tanks regardless of the capacity. The demonstration of this premise remains to be accomplished.

For each of the breakdowns employed in this analysis, an attempt was made to

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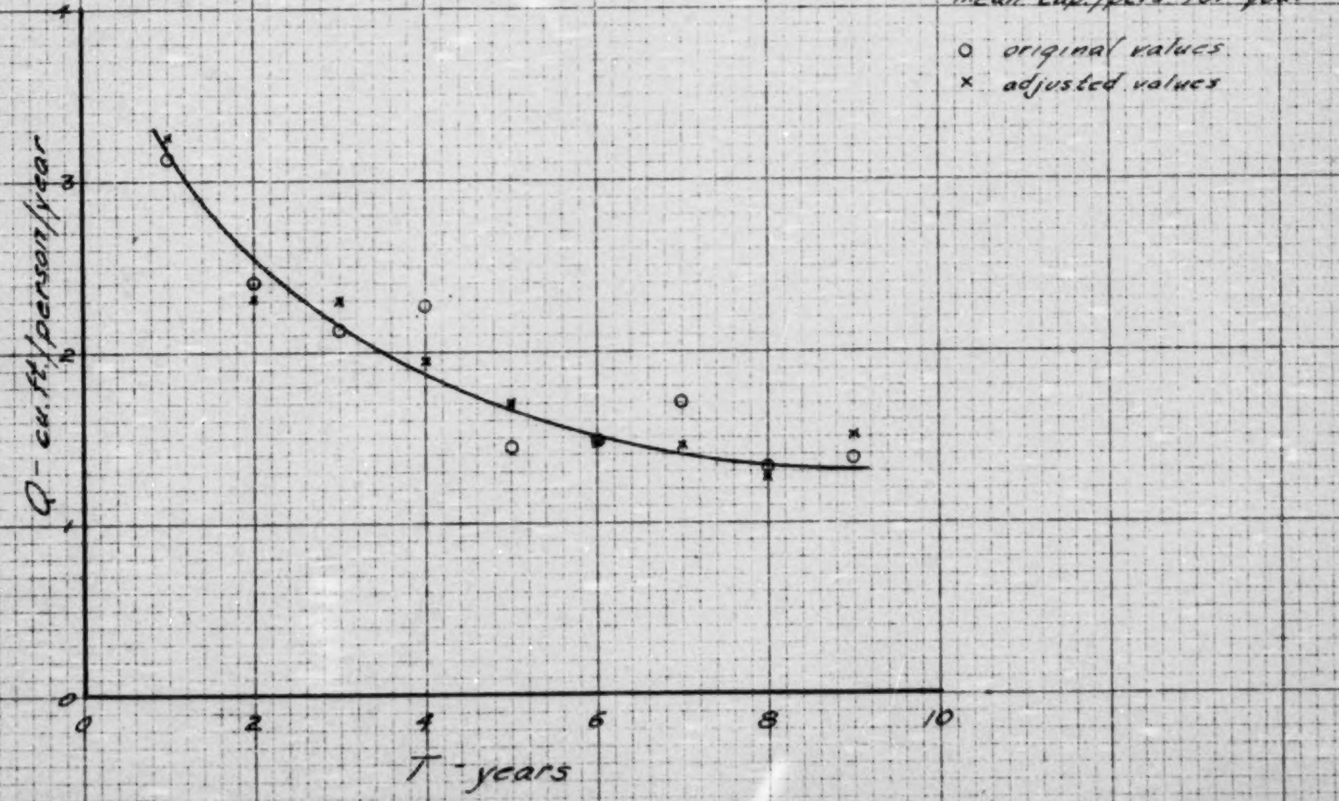
FIG. 4
Accumulation of Sludge + Scum

Mean Rates

Adjusted by proportion of
$\frac{\text{Mean cap./pers. for series}}{\text{Mean cap./pers. for year}}$



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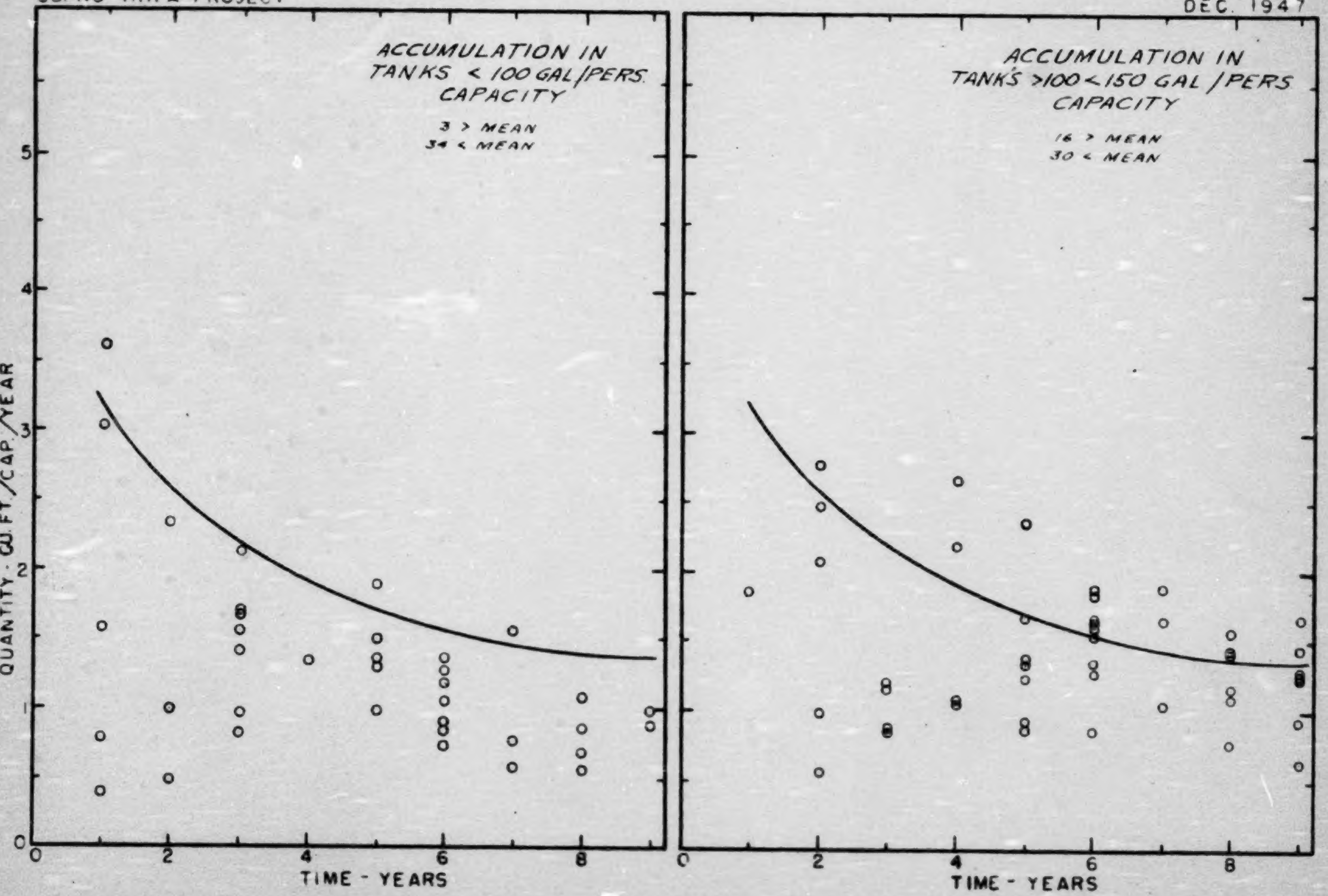

MEAN SLUDGE AND SCUM ACCUMULATION-SEPTIC TANKS

FIG. 5

FIG. 6

1-5-

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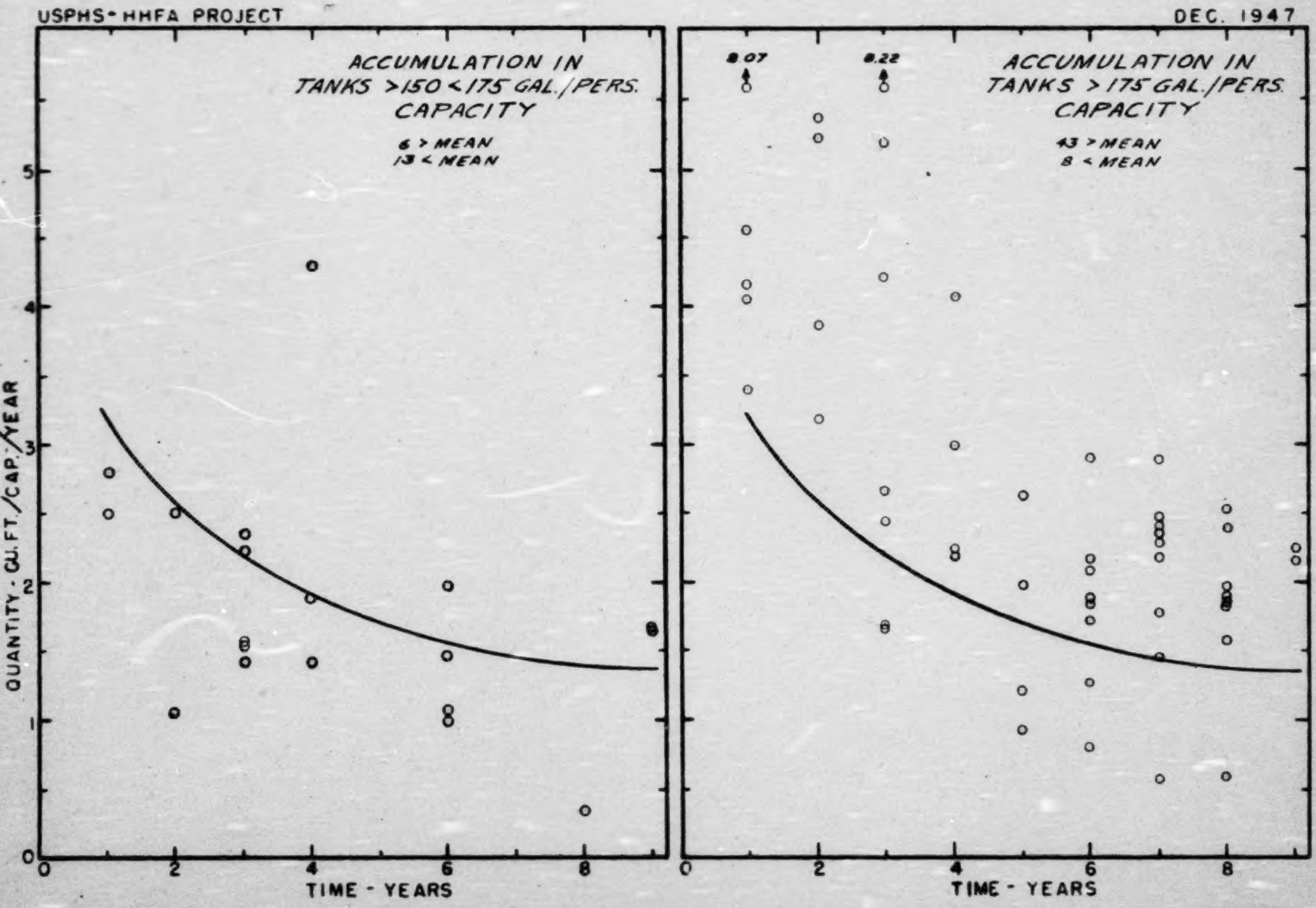

MEAN SLUDGE AND SCUM ACCUMULATION-SEPTIC TANKS

FIG. 7

FIG. 8

prepare mean curves. Thus, a nest of curves would be developed to demonstrate the greater accumulation rates in the larger tanks. However, the individual points varied quite widely for any one curve, and rather than attempt an adjustment, the preceding method was employed to demonstrate this fact. For the lower capacity ranges curves of fairly good fit were obtained. However, for the upper range a curve of quite different shape was obtained, with the rate being almost constant until 4 years, then a sharp drop to a new rate which was practically constant. Whether an adjustment of data would eliminate this has not been determined, nor have any individual points of each capacity range been investigated. It is planned to continue the study of this point with hopes of clarification.

Figs. 9, 10, and 11 show the accumulation of sludge and scum in individual tanks for different ranges of per capita surface area. The groups are; less than 4 sq. ft. per person, between 4 and 6 sq. ft. per person, and, greater than 6 sq. ft. per person surface area. From an inspection of the graphs, it is apparent that the majority of tanks having less than 4 sq. ft. per capita surface area accumulated less than mean quantities of sludge and scum. The tanks in the group over 6 sq. ft. per person, in general, accumulated more than mean quantities. The transition period is in the middle range, and is apparent from an inspection of Fig. 10.

Based on the premise that the most efficient tank is the one accumulating the largest amount of sludge and scum, it appears that tanks having a per capita surface area greater than 6 sq. ft. are the most efficient. This fact is not as clear cut as in the examination of the various capacity ranges, however, the trend is definitely apparent.

The points of each surface area range were not presented as a nest of mean curves due to the facts cited in the preceding sections concerning capacity

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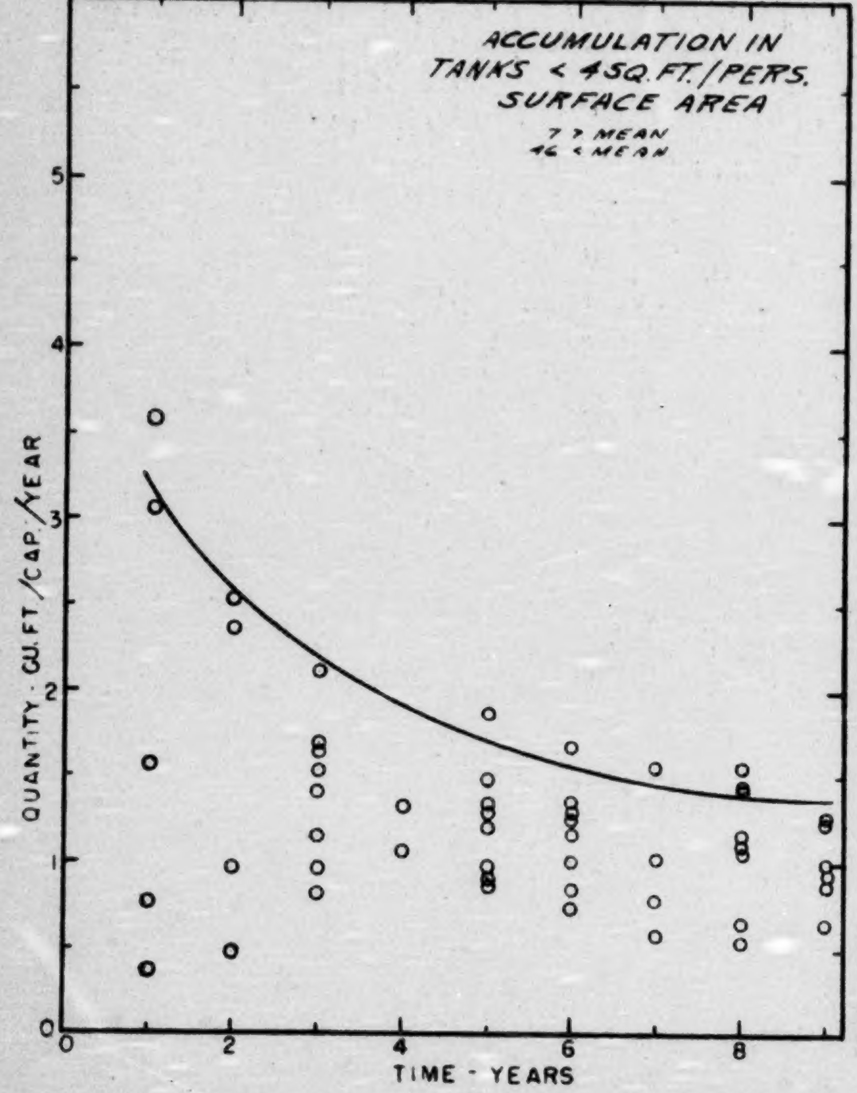
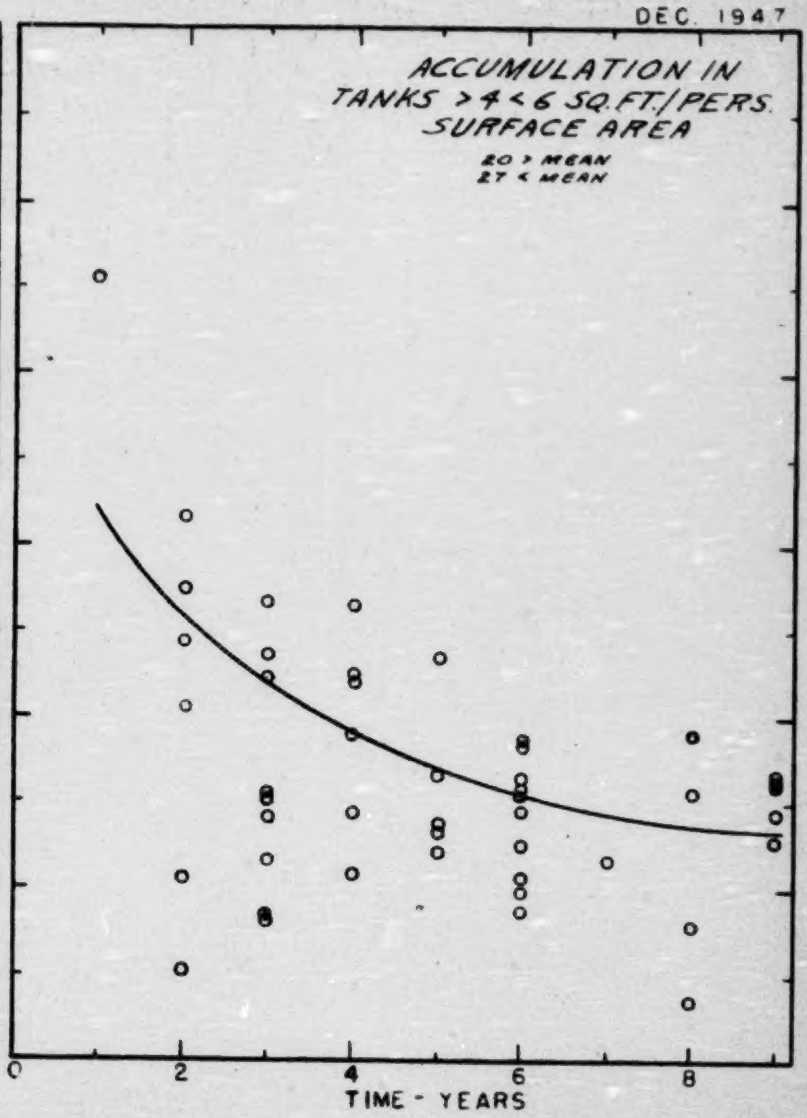


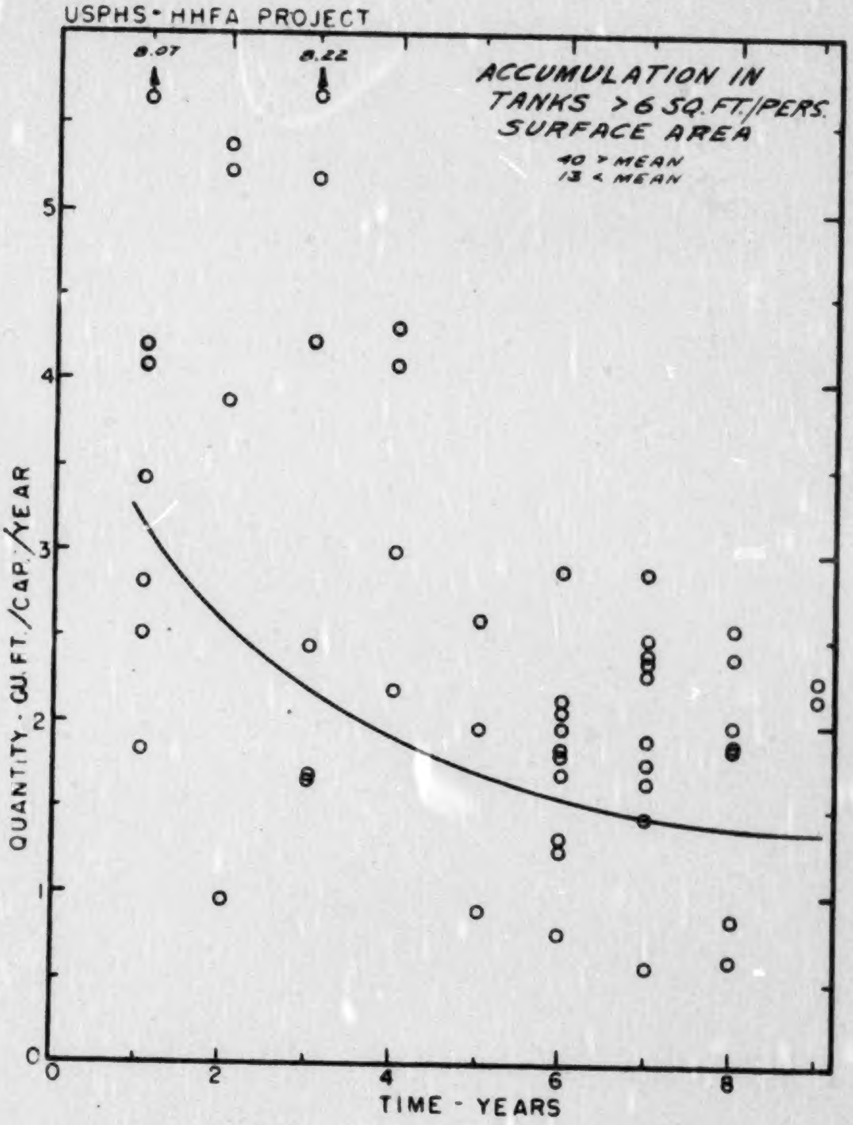


MEAN SLUDGE AND SCUM ACCUMULATION-SEPTIC TANKS

FIG. 9

FIG. 10

1-12-48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8.07
8.22
ACCUMULATION IN TANKS >6 SQ.FT./PERS. SURFACE AREA
40 > MEAN
13 < MEAN
QUANTITY - CU.FT./CAP./YEAR
0
1
2
3
4
5
0
2
4
6
8
TIME - YEARS

FIG. 11

ranges. The mean points for each group gave a poor fit with the expected curve, and adjustment of the data has not yet been attempted.

Multiple Compartment Tanks - Accumulation

Theoretically, the accumulation of sludge and scum in multiple compartment tanks should proceed along certain lines. For instance, in a three chamber tank the accumulation in the first compartment should proceed at a rapid rate initially, gradually becoming less, and finally stopping when the compartment is full. In the second compartment, the rate of accumulation should proceed slowly at first, increase gradually as the rate becomes less in the first chamber, then decrease as the chamber fills up. In the last chamber, the accumulation should proceed at a very slow rate until the final years of useful life of the tank, when the increase should be at a more rapid rate.

Data accumulated in the field on three compartment tanks is shown in Fig. 12 and tends to substantiate the theory postulated above. The data plotted is from a limited number of cases, however, the trend is apparent, and it is reasonable to assume that it would be borne out by additional inspections. For the first and third chambers it is possible to plot a curve closely following the postulated ones, however, it is not possible to delineate the curve for the second compartment as readily.

The first set of curves of Fig. 12 show the percentage of total accumulation in all compartments for each individual compartment. These percentages are equal numerically to those representing the percentage rate of accumulation. By using these curves, and the actual rates of accumulation for the tank as a whole, it was possible to draw the second set of curves representing the accumulation in each chamber.

These curves should not be interpreted as showing what the accumulation

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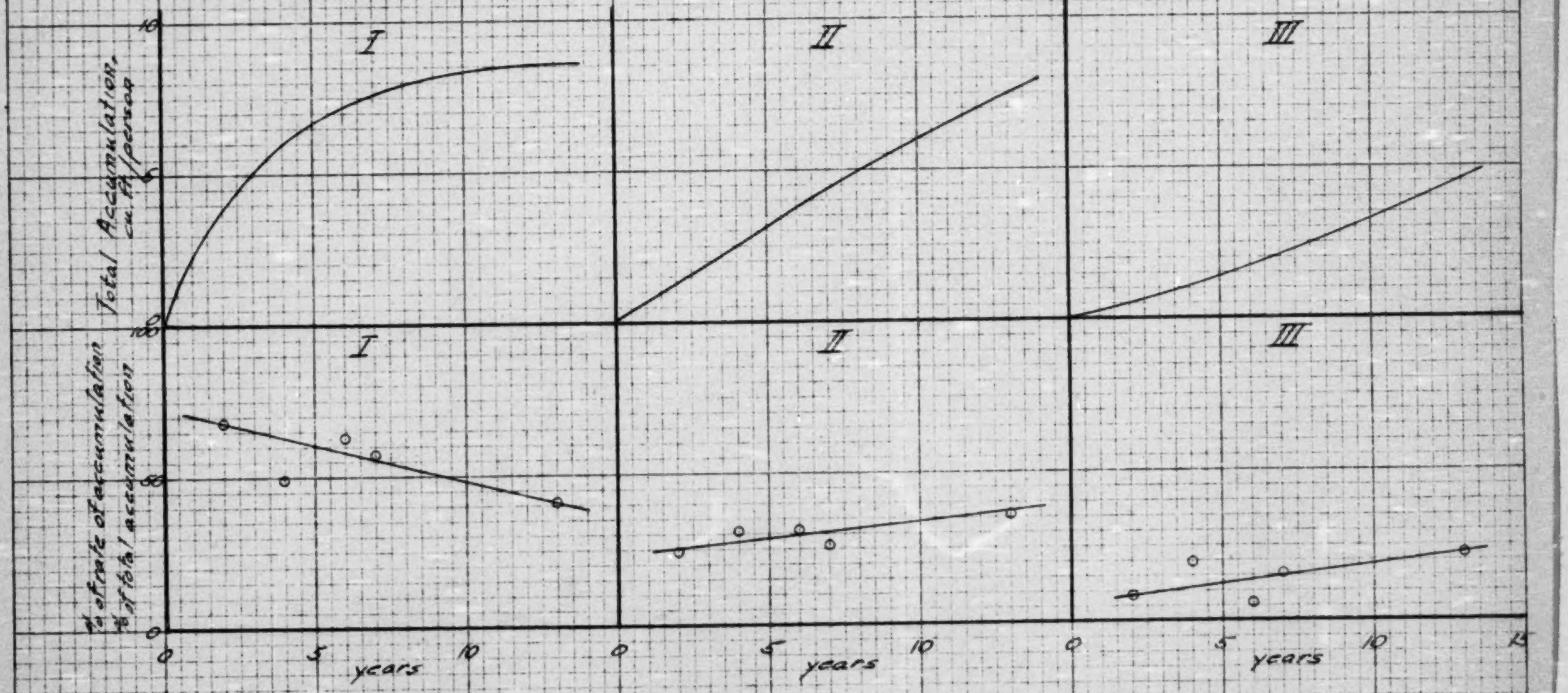
FIG. 12 ACCUMULATION OF SCUM + SLUDGE IN 3-COMPARTMENT TANKS



NO. OBS.	3	3	2	3	3	3	3	2	3	3	3	3	2	3	3
MEAN %	67.8	49.6	62.7	57.3	41.2	24.1	30.7	31.4	26.6	36.5	8.0	19.7	6.0	16.1	22.3
MEAN CAP/PER.	157	162	186	220	195	157	162	186	220	195	157	162	186	220	195

of sludge and scum is in a multiple compartment tank. They represent only a limited amount of data, and are presented only to substantiate the development of the theory concerning accumulation.

Structural Condition

In the course of field inspections the structural condition of the septic tanks was noted. The main conclusion apparent from these observations is that practically all corrosion inside a tank occurs at or above the water line. In general the structural condition of concrete tanks was good, and that of steel tanks, poor. Only a few cases were noted where serious corrosion of concrete tanks had occurred, and this probably was due to an inferior concrete mixture. One particular instance where the concrete baffles were corroded away occurred in a precast tank after only a few years service. The condition of steel tanks is treated more fully in the following sections. Several explanations of the mechanism causing the corrosion have been proposed, however, none have been proved. Experimental work is being conducted which might shed further light on this problem.

The structural condition of steel septic tanks was classified from available field reports. All reports of field inspections of steel tanks were surveyed for use in compiling this summary. However, no definite instructions had been issued to field engineers for judging the structural condition of steel tanks, hence not all reports of steel tank inspections were usable when applying the criteria finally selected. Written statements concerning the tank, as well as photographs made at the time of inspection were used in preparing this summary, and reports of 40 steel tanks were used. The tanks were grouped into four general classifications according to the following criteria. These criteria were adopted from those applied by a steel tank manufacturer in judging the effective life of steel tanks.

Class I. Good - practically no break in coating applied to the tank at time of manufacture.

Class II. Fair - coating starting to break through - bare metal in spots - no holes

Class III. Poor - holes in cover or baffles - rusted

Class IV. Gone - baffles or cover almost rusted away - holes in baffles which allow passage of scum to disposal field.

Table 10. Corrosion of steel septic tanks

		Years in Service			
Class	No. Obs.	Mean	Median	Max.	Min.
I	3	2.5	1	6	0.4
II	9	6	6	12	3
III	14	7	6	11	5
IV	14	9.5	8	17	5

From an analysis of the data presented, it appears that the average useful life of steel tanks is approximately 7 years. It is probable that a longer effective life might be realized, since the criteria of Class III do not infer that any large holes exist, however, the ultimate failure of the tank to provide for normal functions apparently occurs within a short time as evidenced by the mean years of service in Class IV.

In applying the results of this analysis, it must be borne in mind that the effective life of a tank is apparently dependent to a large extent on the effectiveness of the coating applied to the steel. Any cracks or breaks in the coating will materially affect the life of the tank. In judging the probable effective life of any particular tank, consideration should be given to the thickness and composition of the inside coating, and the thoroughness with which it has been applied.

Scum Buoyancy

The buoyancy of the scum in 49 single-chamber septic tanks investigated in the field is shown in the following table.

Table 14. Buoyancy of scum in 49 single - chamber tanks

	% scum above water line	
Mean	28.9	
Minimum	9	
Lower ¼ point	20	)
Median	25	) Normal range
Upper ¼ point	33	)
Maximum	86	

The percentage scum above the water line varies from 9 to 86% with a mean of 28.9% and a median of 25%. The normal range (between the lower and upper quartiles) is 20 to 33%.

The majority of the inspections from which the scum buoyancy data were obtained were conducted on single chamber rectangular tanks in Warwick County, Virginia. For this particular group of tanks in one area, the median percentage was 24.5 and the normal range, 19.5 to 32% of the scum above the water line.

It might therefore be assumed that approximately 25% of the scum will be above the water line, and a corresponding allowance made in tank design criteria. Allowances for this item become appreciable as the tank size and life-service expectancy increase, hence it should not be neglected in tank design.

Tile Field

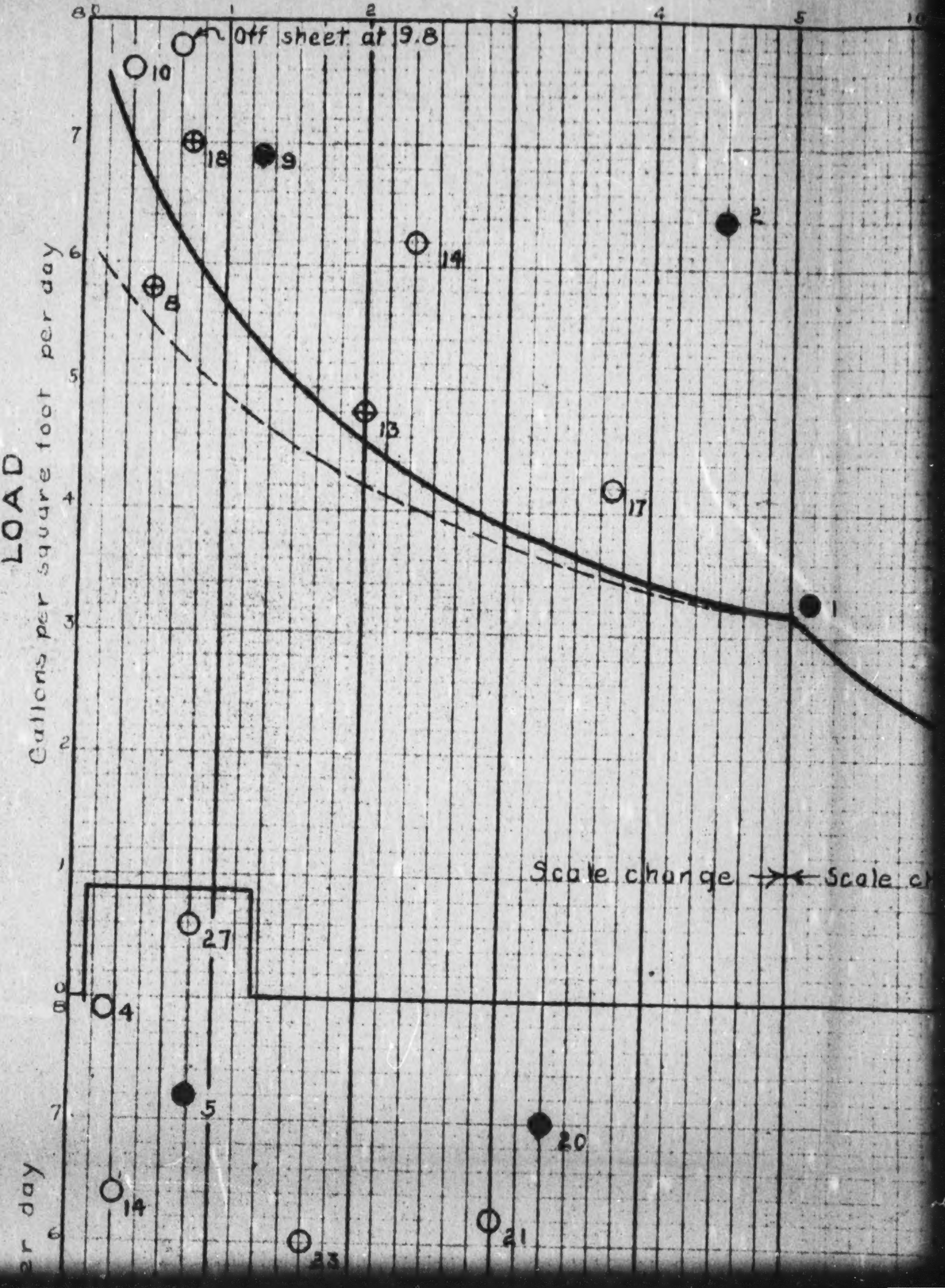
A detailed analysis of the tile fields investigated by field parties is not possible due to a lack of suitable criteria to apply. The correlation of soil analyses, percolation tests, design of fields, and operation has not proven satisfactory, and until some suitable yardstick is developed the investigation of tile fields must be treated as individual case histories.

In the following sections a comparison of field history and design with the standard percolation test has been made. This has been done in two ways; by a comparison of actual soil loading rates in gal./sq. ft./day with the curve developed by Ryon; and, by comparison of absorption areas with percolation test data as published by Ryon and the Joint Committee.

The soil percolation test for determining tile field requirements was originally proposed by the late Henry Ryon in 1928 in an unofficial publication of the New York Department of Public Health. Various attempts were made to locate either Mr. Ryon, or the basic data utilized in preparing this empirical method for estimating the amount of tile needed. After much fruitless search, it became known that Mr. Ryon performed this work while with the New York Department of Public Works, and inquiry of that organization produced the original curve prepared by Mr. Ryon from which the well known percolation test data was developed.

This curve is reproduced in Fig. 13, and in addition to the original data contains information obtained during field inspections of tile field systems carried out for this project. The original data was obtained by Mr. Ryon from personal field observations made over a period of years. The graph is self-explanatory as regards the points used and the final curve drawn, which envelopes all points. It is not known how the determination of the loadings in gallons per square foot per day were obtained; whether they were based on estimates, or on actual water consumption data.

In a letter Mr. Ryon wrote in 1939, he stated that the table commonly used was obtained by simple multiplication using the points on the curve shown in Fig. 13. From a comparison of the points shown on the curve and the data reported by Ryon in his final table, it appears that the daily per capita quantity of sewage estimated was 80 gallons. The determination of this quantity is shown in Table 12. The first two columns of this table comprise the information as



8
0
1
2
3
4
5
10
7
6
5
4
3
2
1
0
8
7
6
LOAD
Gallons per square foot per day
er day
Off sheet at 9.8
10
18
9
2
14
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17
1
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27
4
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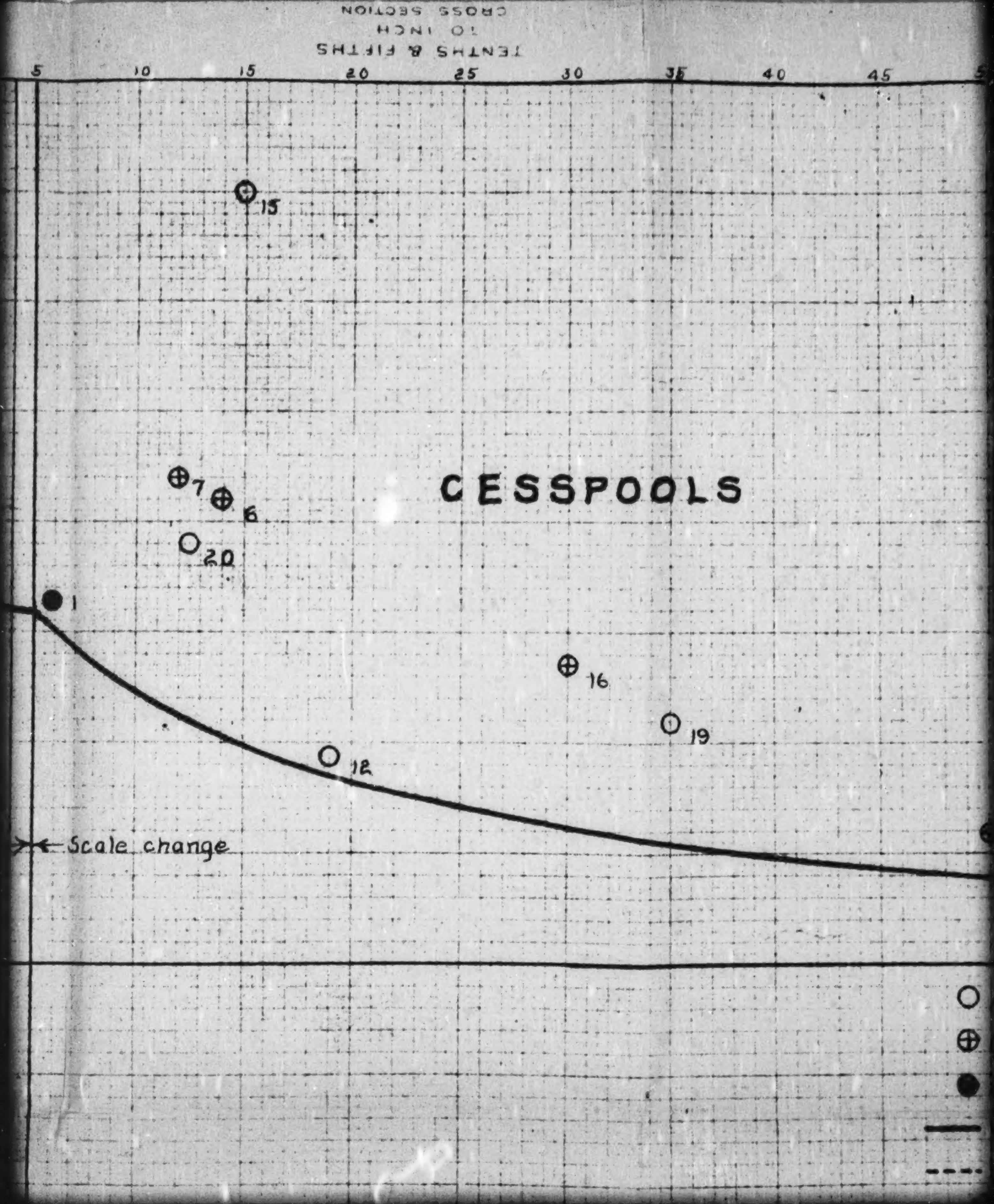
20
14
21
23


TENTHS & FIFTHS
TO INCH
CROSS SECTION
5
10
15
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25
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35
40
45
CESSPOOLS
15
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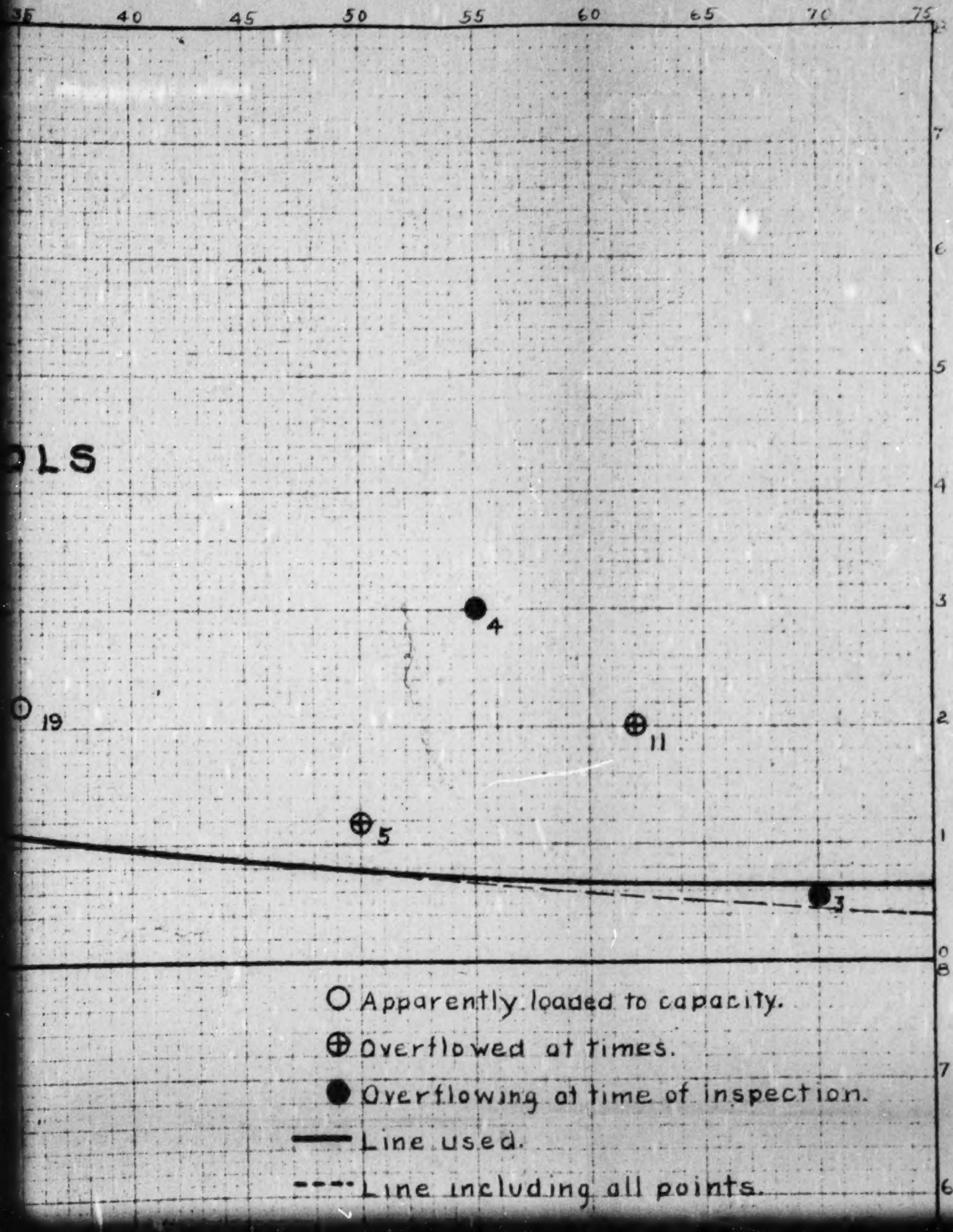
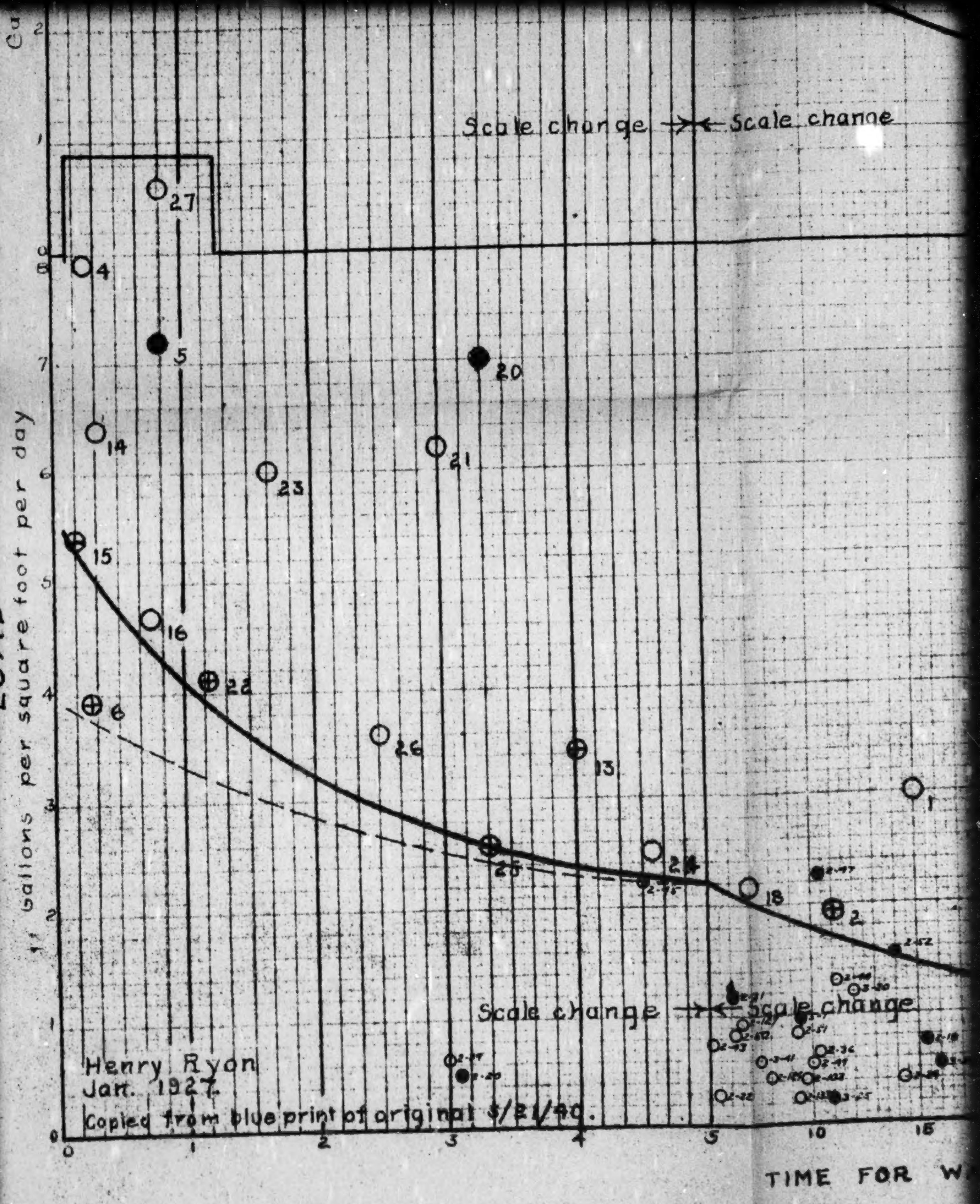
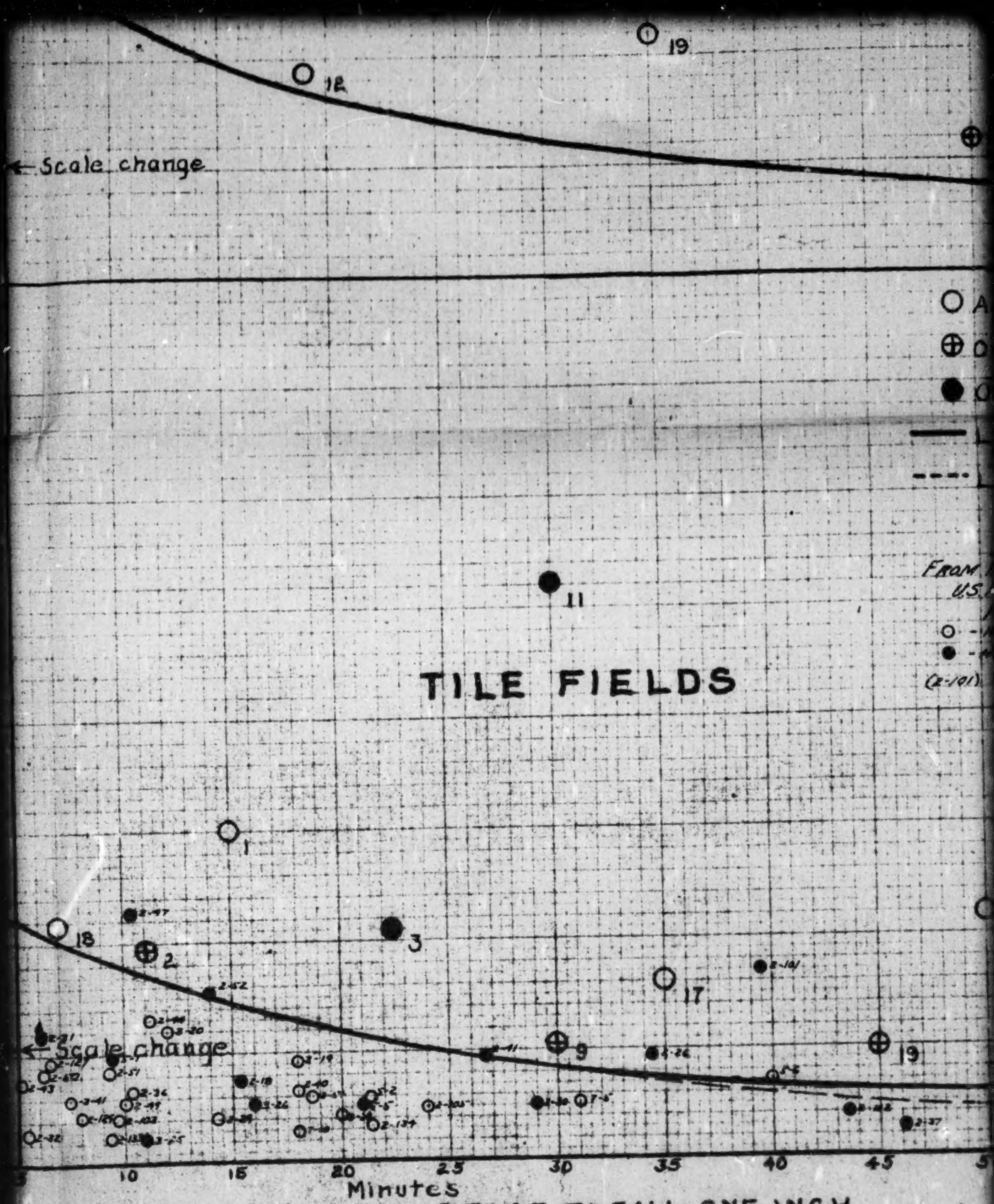
20
1
16
19
12
Scale change


OLS
35
40
45
50
55
60
65
70
75
7
6
5
4
3
2
1
0
8
7
6
19
4
11
5
3
○ Apparently loaded to capacity.
⊕ Overflowed at times.
● Overflowing at time of inspection.
Line used.
Line including all points.

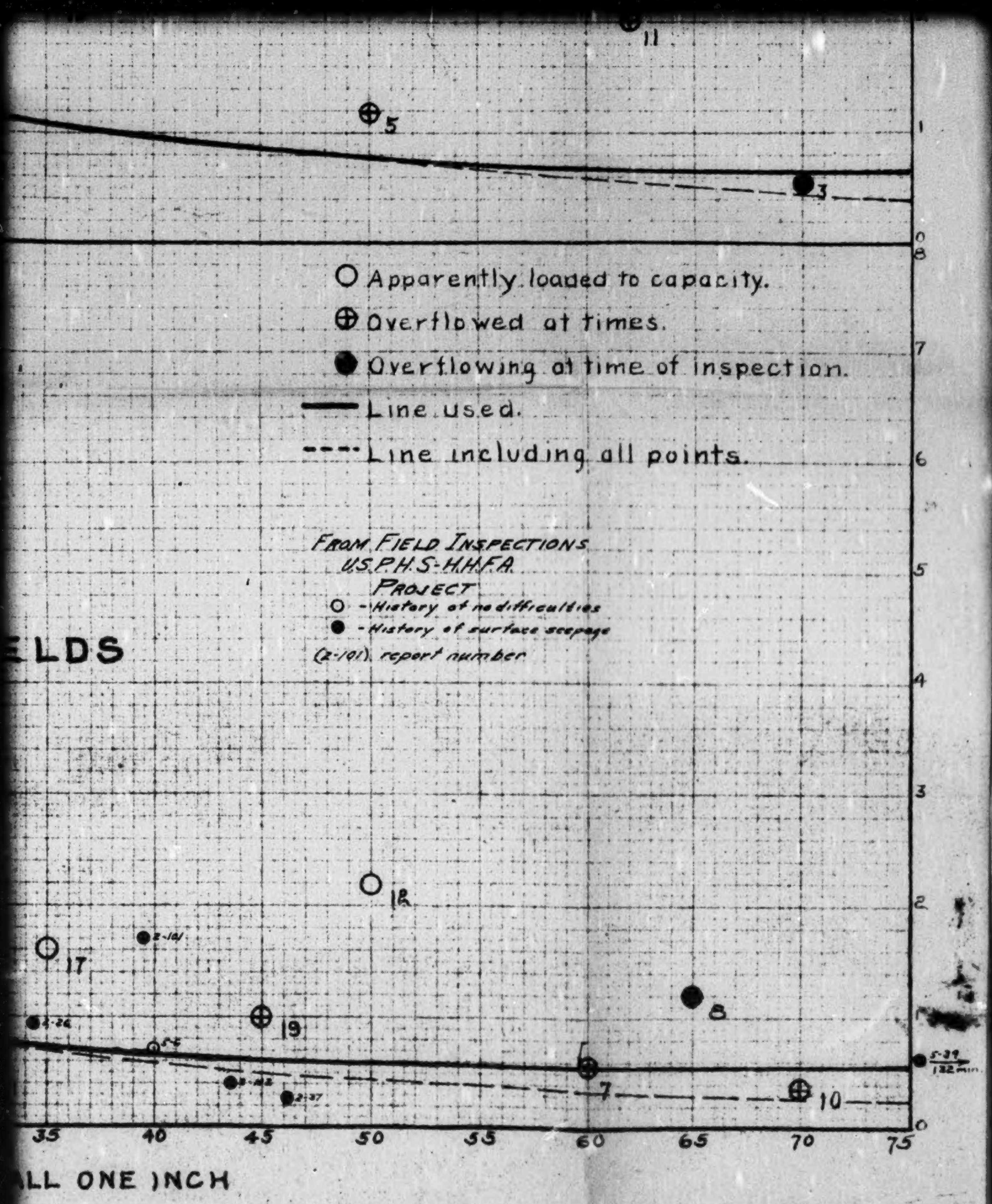


Henry Ryon
Jan. 1927.
Copied from blue print of original 5/21/40.



TIME FOR WATER SURFACE TO FALL ONE INCH

FIG. 13



11
5
3
O Apparently loaded to capacity.
⊕ Overflowed at times.
● Overflowing at time of inspection.
Line used.
Line including all points.
FROM FIELD INSPECTIONS
U.S.P.H.S.-H.H.F.A.
PROJECT
○ - History of no difficulties
● - History of surface seepage
(2-101) report number
ELDS
18
17
2-101
2-26
19
5-5
2-22
2-37
8
7
10
5-39
132 min.
1
0
8
7
6
5
4
3
2
1
0
35
40
45
50
55
60
65
70
75
LL ONE INCH

published by Ryon, and represent the original percolation test data.

Table 12. Quantity of Sewage flow (gcd) used by Ryon in preparing percolation test data

Time to fall 1 inch	sq. ft. of absorption area *	Loading gal/sf/day (from Fig. 13)	Quantity of sewage flow gal/cap/day
1	20	4.10	82.0
2	25	3.24	79.0
3	29	2.71	78.6
4	33	2.37	78.2
5	36	2.20	79.2
10	48	1.78	85.4
15	60	1.45	87.0
30	95	0.84	79.8
45	130	0.61	79.3
60	165	0.56	92.4

*from: Notes on the Design of Sewage Disposal works by Henry Ryon, 1928.

The points plotted on Fig. 13 which were obtained during this survey are based on actual percolation tests made at the time of inspection, and actual water consumption figures. The water consumption data was obtained for both Winter and Summer conditions (usually for a period of 6 months), and the corresponding loading determined. The percolation tests were performed according to the method proposed by Ryon, except that they were allowed to run for one hour or until dry, whichever was shorter. Observations were made at 2 minute intervals for 10 minutes, then at 10 minute intervals for the duration of the test.

Of the 42 points plotted on this graph, only 7 fall in the range where trouble might be expected from a tile field. Six of the tile fields in this group had caused difficulty in that seepage to the ground surface occurred. Only one field in this group was giving satisfactory service, and that point almost falls on the envelope curve. Of the remaining 35 inspections, 11 represent systems at which surface seepage occurred. Based on actual water consumption values, all of these systems should be in the range where satisfactory service would be obtained(using Ryon's premises in developing the percolation test). However, over 30% of the systems in the group were not providing trouble free disposal of septic tank effluent. It is interesting to note that of the nine inspections in which the percolation time was greater than 25 minutes per inch fall, only two systems were operating satisfactorily.

From the data presented here, it appears that the percolation test as originally developed was based on a meager scattering of points from which conclusions were drawn that were not justified by the amount of available data. The data obtained during field inspections of this project does not substantiate the original evolution of the test, but rather tends to destroy it since approximately 1/3 of the systems investigated, which should have been giving satisfactory service, were not.

The percolation test in its present form is subject to such variation as to render its results practically worthless unless applied under varying weather conditions and in a great number of places within the area of the tile field. Its application as an indication of the amount of field required rather than as a dogmatic principle appears to have merit. However, its use should be tempered with due regard for and a wide knowledge of local conditions as they affect the absorption of liquid by the soil. However, until some other form of liquid absorption rating for soils is developed, the percolation test should continue to be used. It is suggested from the plot of points on this curve and in Fig. 14, that a soil might be unsatisfactory when the percolation rate exceed 25 minutes per inch fall. This point needs further study, however, since only a few inspections are involved.

Fig. 14 is a graph showing a comparison between percolation test data and tile fields as actually built. The points are based on the amount of absorption area as determined from field surveys of the system, and actual percolation tests run at the time of inspection. The two curves show the percolation test data as

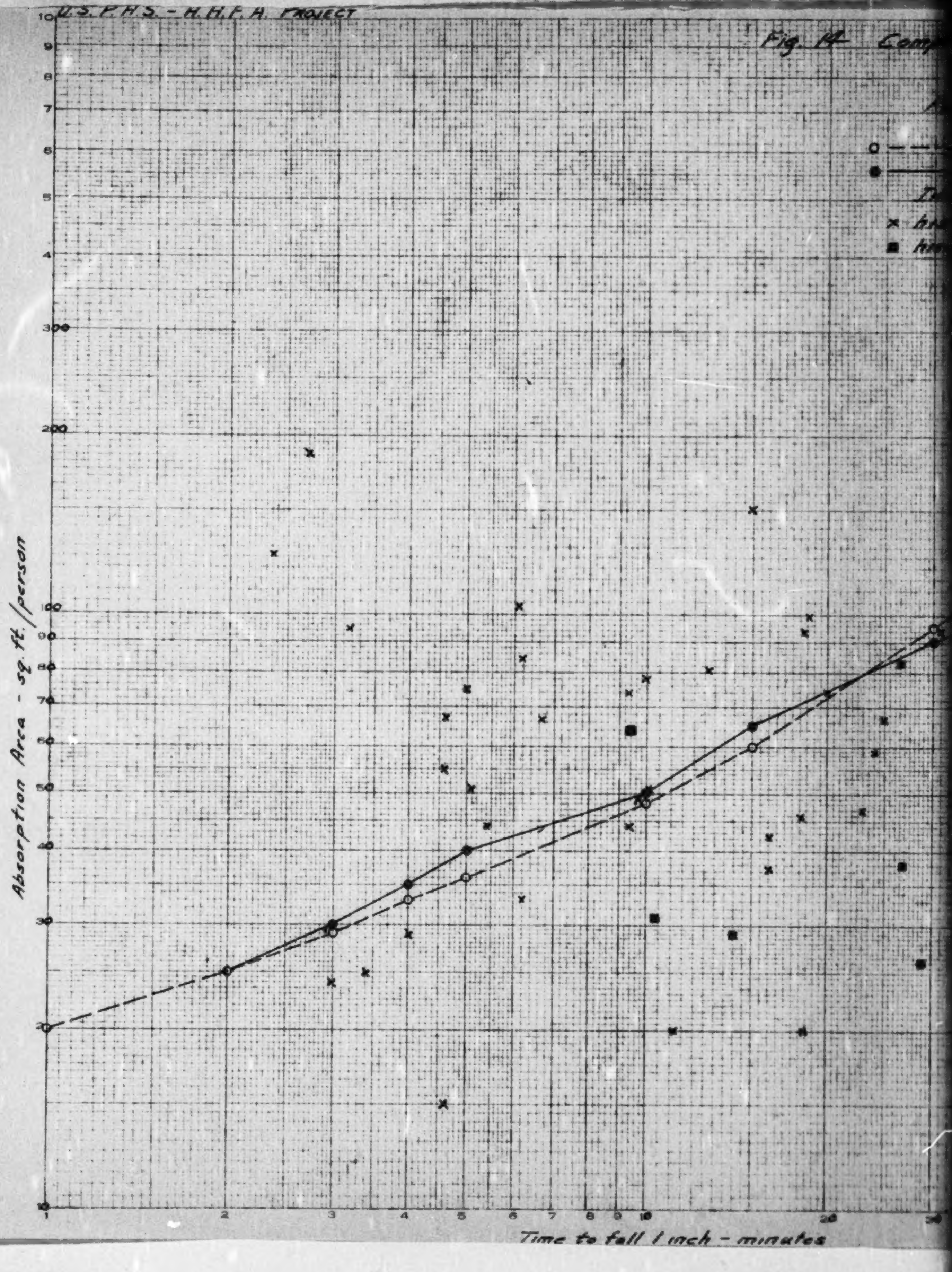
U.S.P.H.S. - H.H.F.A. PROJECT
Absorption Area - sq. ft. / person
Time to fall 1 inch - minutes
10
9
8
7
6
5
4
300
200
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
9
10
20
30
×
■

Fig. 14 Comp

JANUARY 1948

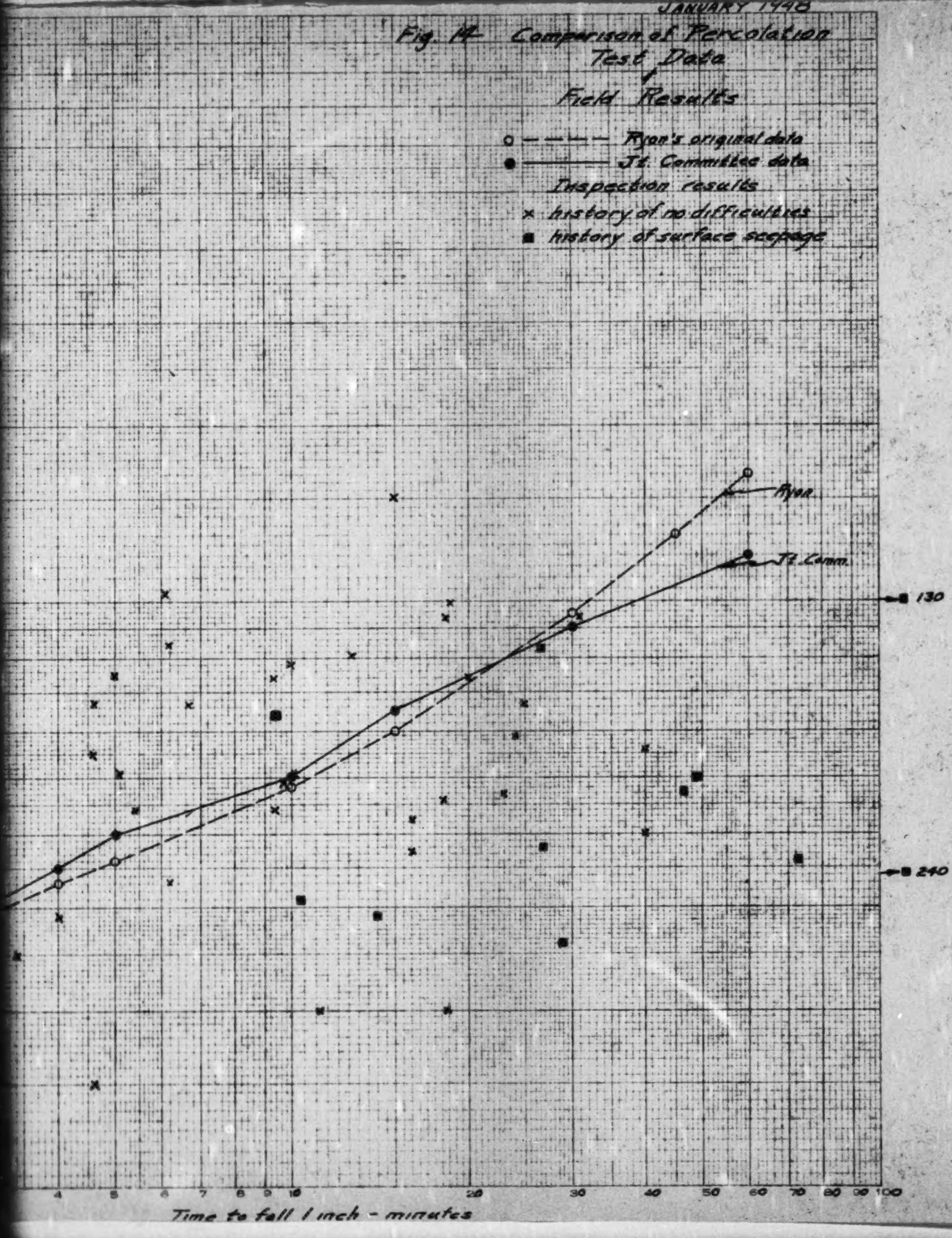


Fig. 14 Comparison of Percolation Test Data & Field Results

proposed originally by Ryon, and that set forth later by the Joint Committee report. It is interesting to note the variation between the two sets of points, however, the difference is due mainly to the rounding off of values by the Joint Committee. There is, however, an unexplained significant difference in the upper range.

Of the 48 tile fields for which adequate information was available, 22 or roughly 46% were above the curves, or in other words, in the region where satisfactory service might be expected. Surface seepage occurred at only one of these. Ten of the 26 systems not having sufficient absorption area as determined by the percolation test caused trouble through seepage to the ground surface.

It should be observed that of the 11 systems having percolation rates in excess of 25 minutes per inch fall, 8 caused surface seepage. This might tend to substantiate further the suggestion that a soil is unsatisfactory when the percolation rate exceeds 25 minutes.

By eliminating all points shown in Fig. 14 where the percolation time exceeds 25 minutes per inch fall, it becomes apparent that no significant difference exists between the points above or below the curves. This tends to substantiate the conclusions expressed earlier concerning the validity of the percolation test, and points to the interpretation of percolation results in view of local conditions rather than as final requirements.

3. Conduct such short term testing and research as may be possible and desirable to substantiate such items as efficiency of sedimentation, adequacy of sludge storage, capacity, size, shape, durability of materials and other comparable characteristics of commercial septic tanks.

Septic Tank

In order to compare the performance of commercial septic tanks, representing common basic shapes in use, plans were made for building or installing several tanks at one location. The site selected for the study had to be so situated that an adequate quantity of reasonably normal fresh sewage would be available at all times. Insofar as possible, the sewage should be comparable to that discharging from the average household unit.

In the Illinois study of septic tank operation, grab samples were collected every sixth day for physical and chemical analyses. In the present study, raw sewage of septic tank effluent samples were collected at each feed and discharge, respectively, composited, and examined in the laboratory. Thus, a continuous record of the materials added to or removed from the individual tanks was obtained and the differences in tank operation noted more directly.

Several possible sites were considered in the Cincinnati area. The experimental phase of the project was located in the greenhouse at the Water and Sanitation Investigations Station, U. S. Public Health Service, Cincinnati, Ohio. The site selected has several advantages, namely: a relatively large quantity of fresh domestic sewage supplied to the Station through a connection with the municipal sewer; proximity to laboratory facilities, thus simplifying sample collection and storage; fairly suitable housing facilities for the project; a caretaker on the property; and all necessary utilities, shops and special maintenance personnel. Following periods of rainfall, dilution of the sewage flows occur, as the Station sewer is connected to a combined sewer.

Originally, difficulties due to the intermittent discharge of acid wastes by a single industrial plant were also experienced. However, through action taken by the city authorities the industrial waste has been diverted.

The number of tanks in operation at any one time has varied. Information relative to tank descriptions and periods of operation is given in tabular form below.

Tank No.	Symbol	Description	Capacity gals.	Period of Operation
1	J1	Joint Committee, rectangular	2060	6/9/47 to date
2	Re	Rounded end	513	"
3	T1	2-36 in. dia. vert. cyl., in series	553	"
4	Ts	4-24 in. dia. vert. cyl., in series	673	"
5	Si	Prefabricated oval	525	"
6	Vc	52 in. dia. vert. cyl.	455	"
7	Js	Joint Committee, rectangular	539	"
8	Hc	52-inch dia. hor. cyl.	492	"
9	Jg	Joint Committee, rect. (garbage & sew.)	539	8/19/47 to date
10	Xl	Joint Committee, rectangular	539	8/20/47 - 10/29/47
11	Xr	Joint Committee, rect. weir outlet	539	8/20/47 - 10/29/47
12	C-1	1-24" dia. vert. cyl.	113	12/4/47 to date
13	C-2	2-24" dia. vert. cyl. in series	216	12/4/47 to date
14	D	24" dia. hor. cyl. tile, 3 comp.	289	1/5/48 to date
15	Jr	Rectangular	539	1/15/48
16	J2	Rectangular, 2 compartment	539	1/15/48
17	J3	Rectangular, 3 compartment	539	1/15/48
18	J4	Rectangular, shallow depth	405	1/15/48

At the start (June 9, 1947), septic tank sludge was obtained from the field for seed purposes, and all tanks were seeded at approximately ten per cent of the volumetric capacity. Thus, the 2000-gallon tank received 200 gallons of seed material and all the other tanks received 50 gallons. In the case of the multi-chambered tanks, each compartment received an aliquot portion of the entire volume of seed, that is, 25 gallons of material were added to each of the two 36" diameter compartments, and 12½ gallons to each of the four 24-inch diameter compartments. The one exception to the latter is the 3-compartment horizontal cylindrical tank. Here all the sludge (10% of volumetric capacity) was added to the first compartment.

Each tank was dosed intermittently eight times daily over a 17-hour period. In the first series of operation, each tank was fed at a rate of 500 gallons per day. In the later series, this rate was reduced to 250 gallons per day. The time and quantity of each feed is given in Table 13, and was determined from a study of individual water use data collected by Station engineers. Tanks are dosed in rotation.

Table 13 Feed Schedule - Septic Tanks

Time of Day	Amount of Feed in Gallons per Tank	
	June 10 - August 18	August 20 - to date
7:00 a.m.	65	32.5
9:00 a.m.	60	30.0
11:00 a.m.	50	25.0
1:30 p.m.	65	32.5
4:30 p.m.	70	35.0
7:00 p.m.	75	37.5
9:30 p.m.	65	32.5
10:30 p.m.*	50	25.0

*This time was changed from 11:00 p.m. to 10:30 p.m. on June 23, 1947.

Three men, working a forty-hour week at staggered hours from 6:30 a.m. to 3:00 p.m. and 3:00 p.m. to 11:30 p.m., feed the units seven days a week, collect the necessary data, and composite the samples. Each man works four days on one shift, has two days off, and then four days on the other shift.

The following information is noted and recorded with each feed; time of feed, volume of feed, air temperature, raw sewage temperature, depth of effluent in collecting tanks, temperature of effluent, and color of effluent. A copy of the data form is included in the Appendix. Chemical data recorded include total solids, total solids ash and volatile, suspended solids, suspended solids ash and volatile, dissolved solids, dissolved solids ash and volatile, pH, and at times alkalinity, grease, B.O.D. and sulfides. The duration of each feed is also noted so that comparisons of rates of feed may be made.

Results - A week was considered to be a satisfactory period of operation for comparison of the results. All data collected were summarized on a weekly basis and all removals and efficiencies computed. Laboratory results were tabulated daily, or twice weekly, depending upon sample compositing time, and from these the following quantities were computed: total solids in pounds, total volatile solids in pounds, suspended solids in pounds, and suspended volatile solids in pounds. Summation of these values permitted estimates of weekly removals of total and suspended solids by each tank and provided a means of computing tank efficiencies. Efficiencies were computed on the basis of the removals in the 500-gallon Joint Committee tank (No. 7), but since tank performance was erratic, more suitable comparisons were possible using the 2000 gallon Joint Committee tank (No. 1) as a base.

Scum and sludge measurements were made at the end of each week of operation. Sludge sounding and scum measuring rods similar to the type developed for field use were utilized and have been described previously.

Scum measurements were made at the influent and effluent ends of the tanks, and sludge measurements at several points in all tanks. The number of points selected was dependent upon the size and shape of the tank.

Scum and sludge volumes covering the entire period of operation to date are given in Tables 14 and 15 respectively, and sludge volumes are shown graphically in Figs. 15 & 16. Sludge volumes are only relative since the compactness of the sludge is not known. Actually the sludge in the tanks is a fluid type of sludge and is not compact.

It will be noted that there has been no scum in the 2000 gallon Joint Committee tank since the start.

Table 14 Scum Volume in Cubic Feet

Tank	6/24/47	7/1/47	7/8/47	7/15/47	7/22/47	7/29/47	8/5/47	8/12/47	8/19/47	8/27/47	9/3/47	9/10/47	9/17/47
1	–	–	–	–	–	–	–	–	–	–	–	–	–
2	(0.70)	(1.16)	(1.40)	(1.40)	(0.98)	(0.56)	(0.56)	(0.51)	(0.23)	(0.05)			
	0.75	1.25	1.50	1.50	1.05	0.60	0.60	0.55	0.25	0.05	–	–	–
3	–	0.5+	0.02+	0.08	1.31	2.23	2.04	2.99	2.48	2.13	2.49	2.02	0.60
3a	–	–	–	0.02	1.29	2.17	1.61	2.65	2.24	2.11	2.47	1.96	0.17
3b	–	0.5	0.02	0.06	0.02	0.06	0.43	0.34	0.24	0.02	0.02	0.06	0.43
4	0.26+	0.47+	1.19	1.56	1.74	1.13	1.10	2.19	3.04	1.80	1.82	1.73	0.73
4a	–	tr	0.87	1.15	1.14	0.93	0.72	1.39	1.69	0.98	1.10	1.40	0.54
4b	0.13	0.18	0.30	0.38	0.58	0.08	0.21	0.59	1.01	0.81	0.70	0.33	0.19
4c	0.13	0.27	0.01	0.02	0.01	0.11	0.16	0.19	0.27	0.01	0.01	–	–
4d	tr	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.07	tr	0.01	–	–
5	0.94	1.27	2.39	1.27	0.05	0.37	0.50	0.42	0.37	0.05	–	–	–
6	1.57	1.57	1.21	1.44	0.49	0.31	0.49	0.54	0.27	0.05	–	–	–
7	1.48	1.42	1.28	1.63	0.12	0.47	0.47	0.59	0.18	0.06	–	–	0.18
8	0.61	1.22	1.25	1.07	0.91	0.61	0.61	0.91	0.61		–	–	
9										0.06	0.30	0.71	0.59
10Xl										0.06	–	–	–
11Xr										0.06	–	0.24	–

*Area of baffles subtracted

Table 15

Tank	June 24, 1947	July 1	July 8	July 15	July 22	July 29	Aug. 5	Aug. 12	Aug. 19	Aug. 27
1	14.98	15.88	9.39	-	16.16	15.80	14.80	17.80	16.00	16.21
2	1.99	1.74	1.44	-	1.44	1.93	2.02	2.10	1.87	2.54
3	2.36+	3.85+	5.16	-	4.00	4.99	3.89	4.04	4.18	4.64
3a	2.36	3.85	4.54	-	3.38	4.00	3.27	3.42	3.32	3.93
3b	0.71-	0.62-	0.62	-	0.62	0.99	0.62	0.62	0.86	0.71
4	5.19	5.73	4.37	-	3.40	4.88	5.73	4.19	3.20	4.77
4a	1.78	2.70	2.38	-	2.06	3.57	4.52	2.75	1.73	2.81
4b	0.88	0.65	0.74	-	0.32	0.38	0.51	0.34	0.50	0.49
4c	1.04	1.26	0.32	-	0.32	0.32	0.32	0.54	0.69	0.75
4d	1.49	1.12	0.93	-	0.70	0.61	0.38	0.56	0.28	0.72
5	3.10	3.08	1.54	-	3.76	1.88	2.88	3.71	3.74	4.03
6	1.48-	1.79	1.35	-	2.20	1.93	1.62	2.34	2.03	2.83
7	2.88	1.96	1.72-	-	3.22	2.52	2.67	3.10	3.01	3.80
8	0.67	0.34-	0.36	-	0.91	1.46	1.58	1.40	2.16	1.86
9Jg										1.72-
10Xl										1.72-
11Xr										1.72-
C1										
C2										
a										
b										

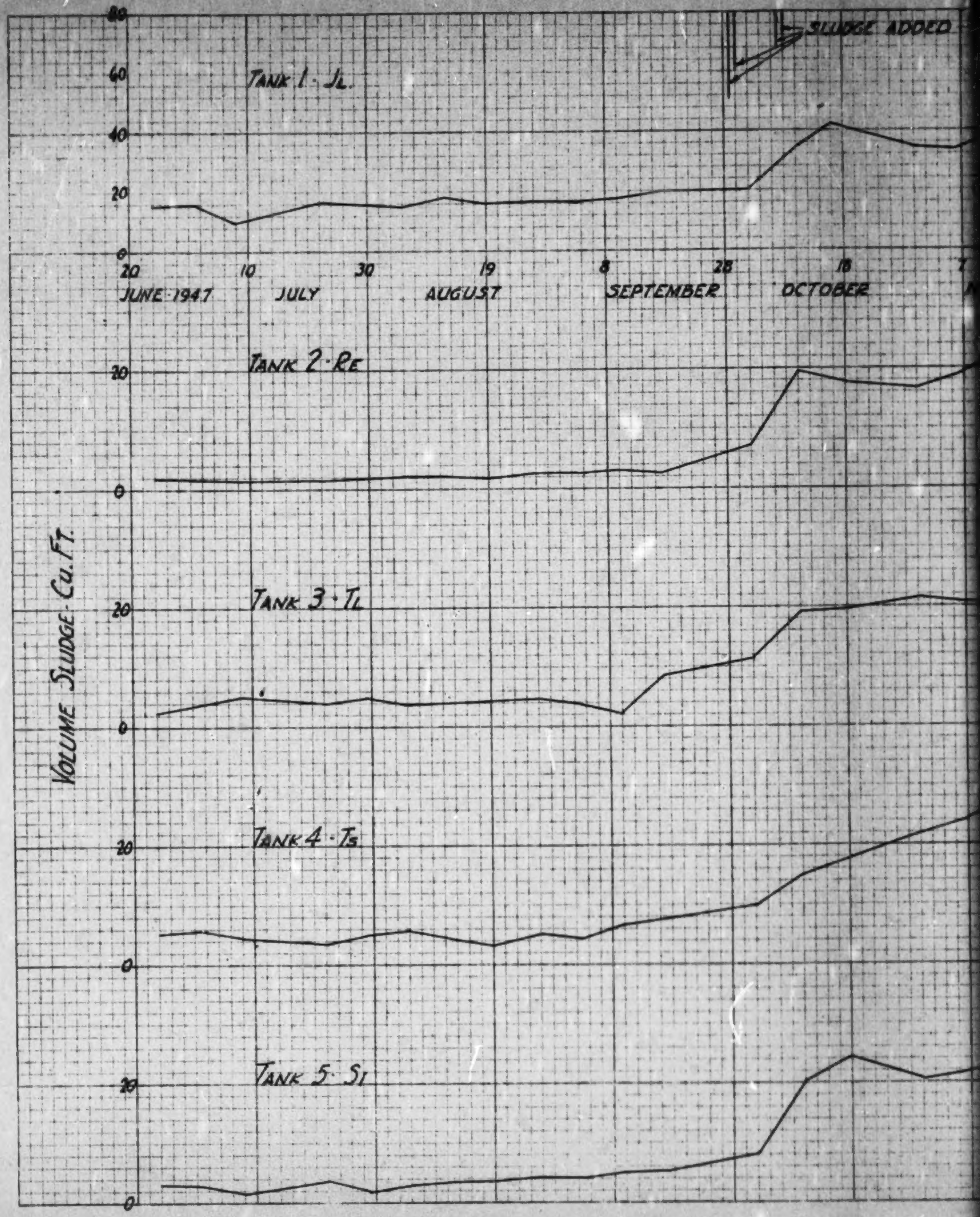
*Measurements probably made before sludge settled completely after overturn.

Table 15 Sludge Volumes in Cubic Feet

29	Aug. 5	Aug. 12	Aug. 19	Aug. 27	Sept. 3	Sept. 10	Sept. 17	Oct. 2	Oct. 10	Oct. 16	Oct. 30	Nov.
	14.80	17.80	16.00	16.21	16.42	17.31	19.50	20.0	34.1	41.8	34.5	33.6
	2.02	2.10	1.87	2.54	2.59	3.09	2.47	7.35	19.57	17.78	16.60	18.9
	3.89	4.04	4.18	4.64	3.98	2.13	8.64	11.22	19.11	19.62	21.66	20.6
	3.27	3.42	3.32	3.93	3.01	1.05	5.35	8.17	15.45	16.50	16.22	14.5
	0.62	0.62	0.86	0.71	0.97	1.08	3.29	3.05	3.66	3.12	5.44	6.0
	5.73	4.19	3.20	4.77	4.33	6.47	7.49	9.94	14.79	-	21.87	23.9
	4.52	2.75	1.73	2.81	1.89	2.97	3.26	5.03	6.91	-	9.48	10.3
	0.51	0.34	0.50	0.49	0.72	1.13	1.65	1.42	4.97	-	8.16	8.9
	0.32	0.54	0.69	0.75	0.70	1.14	1.30	1.94	1.62	-	2.65	3.0
	0.38	0.56	0.28	0.72	1.02	1.23	1.28	1.55	1.39	-	1.58	1.5
	2.88	3.71	3.74	4.03	4.03	4.98	5.15	8.05	20.3	24.3	20.5	21.5
	1.62	2.34	2.03	2.83	2.26	3.43	3.34	4.87	17.4	22.5*	15.98	18.4
	2.67	3.10	3.01	3.80	3.49	6.05	5.12	6.29	16.0	18.09	15.53	29.3
	1.58	1.40	2.16	1.86	2.31	3.04	3.27	4.17	12.91	15.50	11.23	12.4
				1.72-	1.80-	2.21	4.05	6.70	14.08	-	14.11	15.1
				1.72-	1.72-	1.72-	1.72	-	-	-	8.95	
				1.72-	1.72-	1.72-	1.72-	-	-	-	7.81	

ly after overturn.

. 2	Oct. 10	Oct. 16	Oct. 30	Nov. 6	Nov. 24	Dec. 1	Dec. 8	Dec. 15	Dec. 22	Dec. 29	Jan. 5
0	34.1	41.8	34.5	33.6	47.7	47.0	52.7•	48.0	56.0	55.92	56.10
35	19.57	17.78	16.60	18.90	28.0	26.5	25.7	25.7	24.0	21.12	22.11
22	19.11	19.62	21.66	20.61	20.23	29.8	29.9	28.93	31.60	30.38	27.29
17	15.45	16.50	16.22	14.53	13.58	21.2	21.1	20.35	19.90	20.96	18.43
05	3.66	3.12	5.44	6.08	6.65	8.6	8.8	8.58	11.70	9.42	8.86
94	14.79	-	21.87	23.97	32.87	33.23	33.65	32.68	32.42	34.07	31.93
03	6.91	-	9.48	10.31	13.30	14.08	13.80	14.08	13.60	13.59	12.87
42	4.97	-	8.16	8.99	10.60	12.27	11.53	10.84	10.86	12.49	10.41
94	1.62	-	2.65	3.08	5.30	5.06	6.00	5.65	5.80	5.80	6.00
55	1.39	-	1.58	1.59	3.67	1.82	2.32	2.11	2.16	2.19	2.65
05	20.3	24.3	20.5	21.5	26.0	24.9	32.7	31.0	33.1	29.52	28.30
87	17.4	22.5•	15.98	18.44	29.0•	25.4	25.4	23.7	25.5	25.91	27.48
29	16.0	18.09	15.53	29.35•	26.9	28.3	28.7	27.2	26.7	26.15	26.98
17	12.91	15.50	11.23	12.43	21.5	23.8	19.22	18.90	18.61	21.5	20.10
70	14.08	-	14.11	15.18	25.7	36.6•	26.5	26.7	27.4	28.70	27.12
-	-	-	8.95								
-	-	-	7.81								
							0.52	0.77	1.62	-	2.00
							0.85	1.46	2.25	2.94	3.86
							0.59	1.15	1.64	2.17	3.04
							0.26	0.31	0.61	0.77	0.82


SLUDGE ADDED
TANK 1 · JL
TANK 2 · RE
TANK 3 · TL
TANK 4 · TS
TANK 5 · SI
VOLUME SLUDGE · CU. FT.
80
60
40
20
0
20
10
30
19
8
28
18
7
JUNE · 1947
JULY
AUGUST
SEPTEMBER
OCTOBER

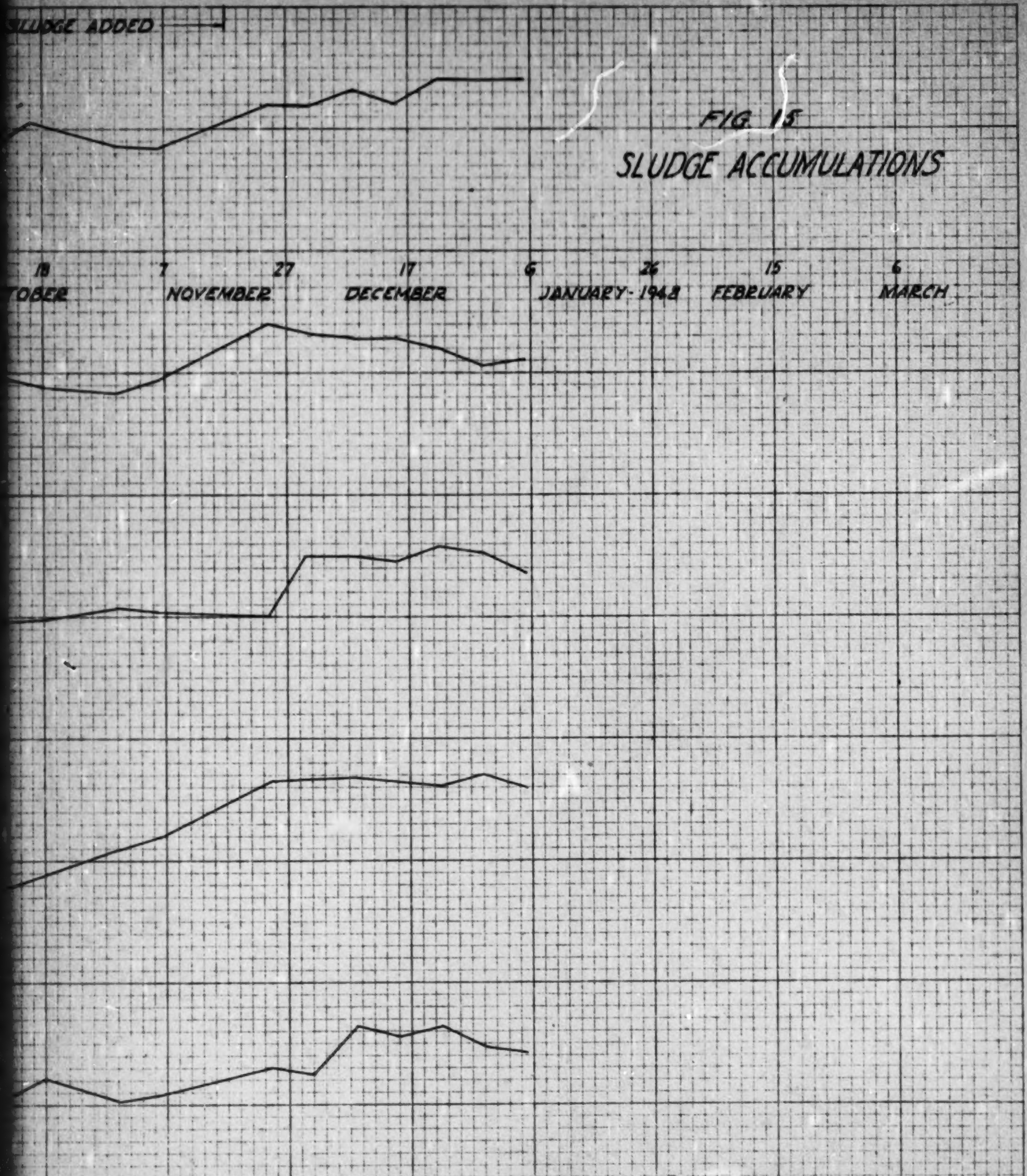
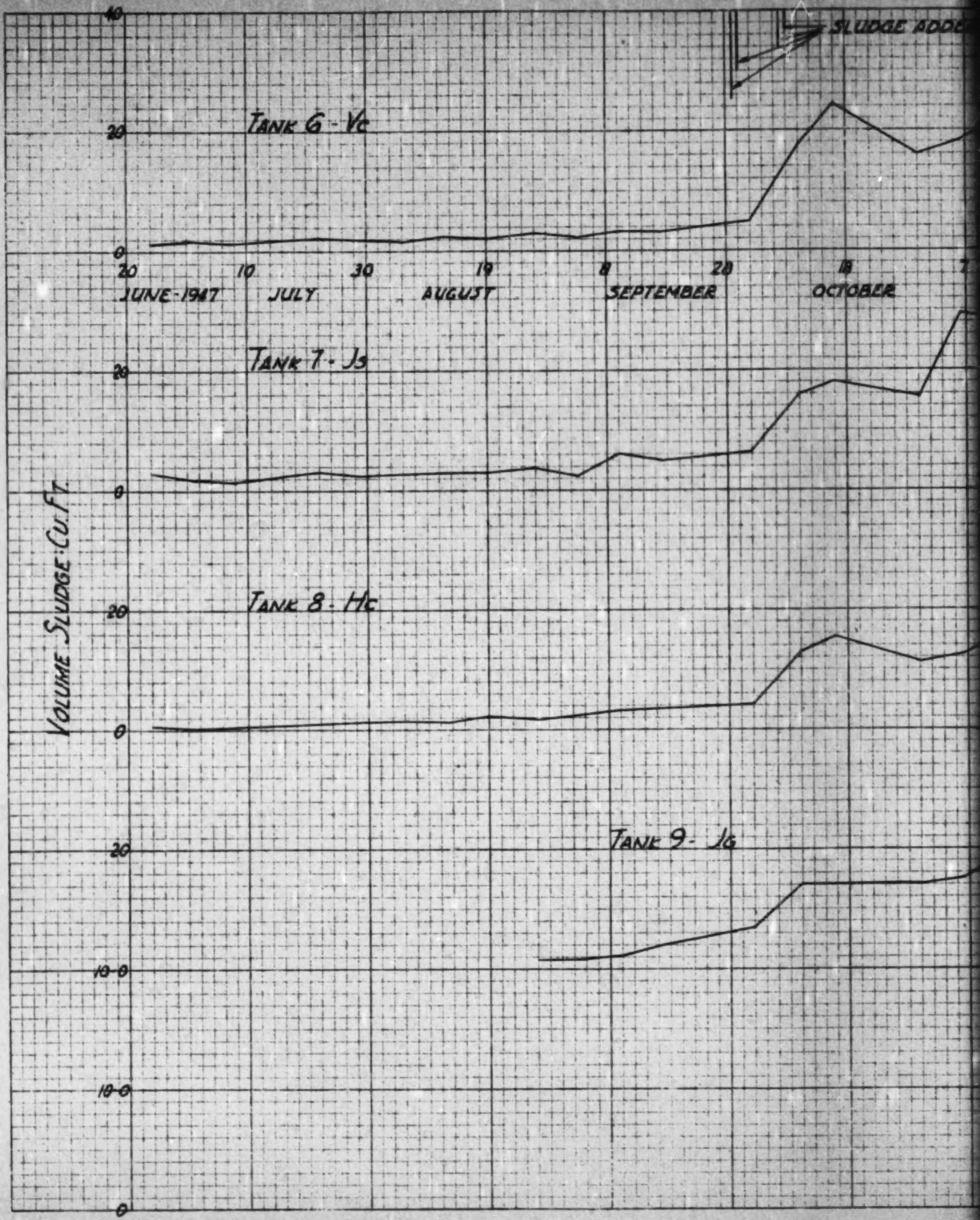


FIG 15

SLUDGE ACCUMULATIONS



SLUDGE ADDE
40
Tank 6 - Vc
20
0
20
10
30
19
8
28
18
JUNE-1947
JULY
AUGUST
SEPTEMBER
OCTOBER
Tank 7 - Js
20
0
Volume Sludge · Cu. Ft.
Tank 8 - Hc
20
0
Tank 9 - Jg
20
10-0
10-0
0

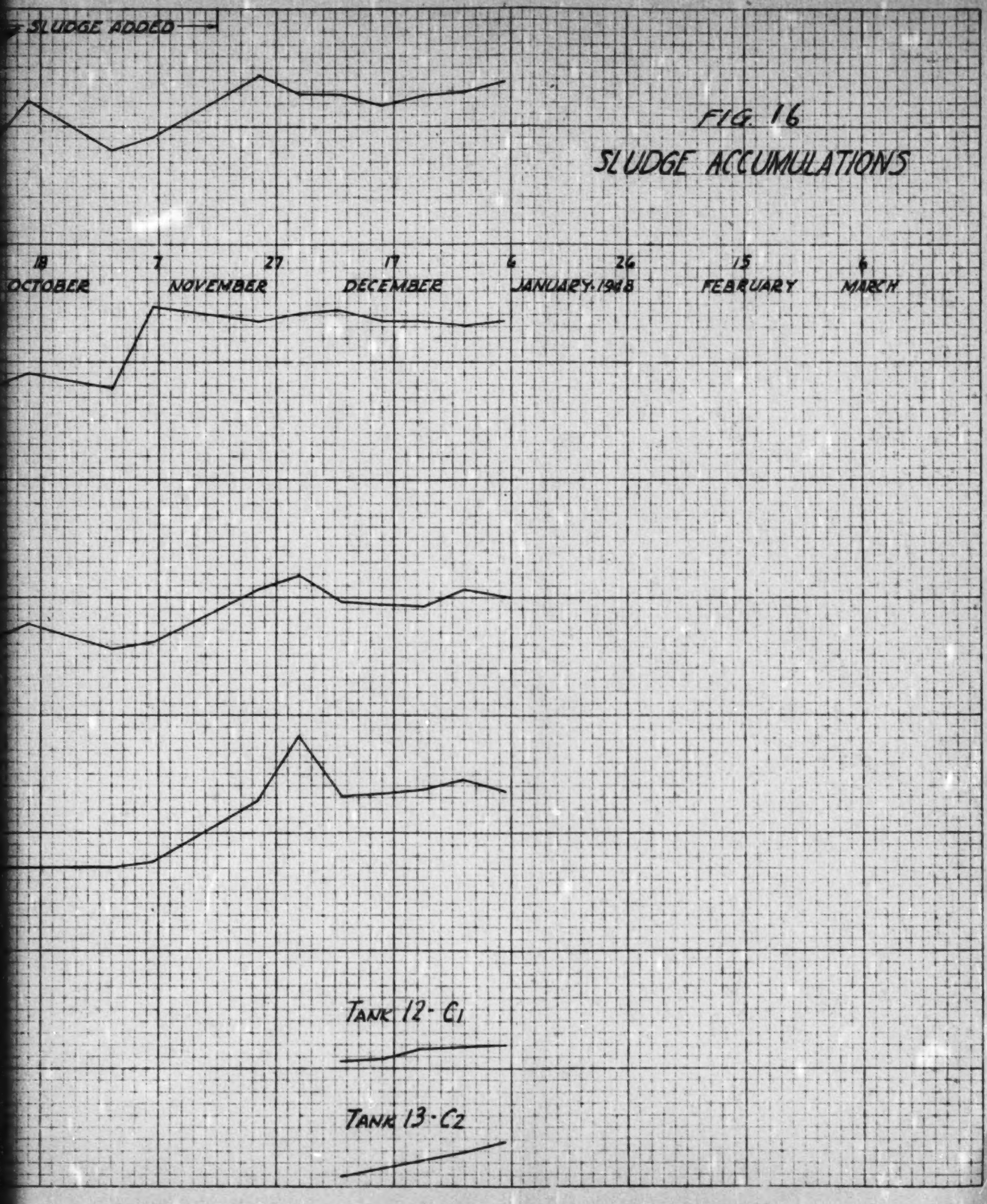


FIG. 16
SLUDGE ACCUMULATIONS

Chemical examinations of the total solids and volatile contents of the scums and sludges have been made from time to time, and the data have been reported previously. A sampler was developed for collecting sludge for analysis.

The first series of operation (tanks No. 1 through 8) extended from June 10 to August 18, 1947. Five hundred gallons of fresh raw sewage were fed to each tank daily.

The dosage rate of 500 gallons per day per tank is higher than that which would normally occur in a four or five person household. It may be said, therefore, that all tanks were overloaded with the exception of the 2000 gallon Joint Committee tank which would serve more than 16 people. Weighted average results for this series of operation are given in Table 16.

A study of these results indicate that there were great differences in the operating efficiencies of the tanks. The removal of suspended solids varied from 17.9 to 60.1 per cent based on the raw sewage added during the period, with the highest removal shown by the 2000 gallon Joint Committee tank. The 4-chamber (No. 4) and 2-chamber (No. 3) tanks showed removals of 56.4 and 59.0 per cent, respectively. Of the remaining tanks, the horizontal cylindrical tank (No. 8) had the highest removal (38.6 per cent). The other tanks showed removals of 17.9 to 26.4 per cent with the vertical cylindrical tank (No. 6) giving the lowest removal.

On the basis of a 10-day series of tests, the B.O.D. removals varied from 35.1 to 60.2 per cent, with the highest reduction in B.O.D. shown by the 4-chambered tank.

On August 20 the rate of feed was reduced to 250 gallons per tank per day and all tanks were fed at this rate until September 23, 1947. The results obtained during this interval of operation (second series) are given in summary

Table 16 Sewage & Effluent Characteristi

1st Series - 500 gal/day feed - June 10 - Aug.

Item	Raw	1 - Jl	2 - Re	3 - Tl	4 - Ts	5 -
Raw sewage added-gal.	33,785					
Total solids - ppm.	986	740	869	761	747	
T.S. ash-ppm.	504	462	489	453	444	
T.S. vol. -ppm.	482	278	378	310	301	
Sus. Solids. ppm.	348	149	261	147	157	
S.S. ash-ppm.	77	53	86	41	51	
S.S. vol.-ppm.	271	96	175	105	107	
Dissolved Solids - ppm.	638	592	605	613	591	
D.S. ash-ppm.	427	415	401	407	394	
D.S. vol.-ppm.	212	117	203	206	195	
pH	7.3	7.5	7.3	7.4	7.4	
B.O.D.- ppm.	370	174	240	177	147	
Grease	-					
B.O.D.% red.		53.0	35.1	52.1	60.2	
Sludge vol. cu. ft. (8/19)	-	16.0	1.87	4.2	3.2	
Scum vol. cu. ft. (8/19)	-	0	0.25	2.5	3.0	
#'s solids (sewage) added		278.018	278.765	278.197	278.373	278.
#'s " (effluent)		194.823	243.696	210.047	206.413	244.
#'s " removed		83.195	35.069	68.150	71.960	33.
% T.S. reduction based on R.S. added (1)		29.9	12.6	24.5	25.8	
% T.S. " " " total " (2)		39.7	16.0	27.4	28.7	
#'s suspended (sewage) added		98.678	98.853	98.713	98.733	98.
#'s " (effluent)		39.401	73.272	40.529	43.270	78.
#'s " removed		59.277	25.581	58.184	55.463	20.
% S.S. red. based on R.S. added		60.1	26.4	59.0	56.4	
% S.S. " " " total added		64.7	27.8	60.0	57.3	

(1) For the period June 10 - Aug 18, 1947
(2) For the period June 10 - Aug.18, 1947 - includes seed material

Table 17 Sewage & Effluent Characteristi

2nd Series - 250 gal./day - August 20 - Septemb

Item	Raw	1 - Jl	2 - Re	3 - Tl	4 - T_s	5 -
Raw sewage added-gal.	7492.5					
T.S. - ppm.	821	609	646	669	600	
T.S. ash-ppm.	463	418	421	420	409	
T.S. vol.-ppm.	359	191	224	249	193	
S.S.- ppm.	312	76	125	131	73	
S.S. ash-ppm.	73	18	49	41	19	
S.S. vol.-ppm.	241	59	89	91	53	
Dis. Sol.- ppm.	512	533	520	538	527	
D.S. ash -ppm.	392	400	385	378	388	
D.S. vol.-ppm.	120	133	136	159	141	
pH	7.3	7.5	7.4	7.4	7.4	
B.O.D.-	368	148	172	169	146	

able 16 Sewage & Effluent Characteristics

eries - 500 gal/day feed - June 10 - Aug. 18, 1947

2 - Re	3 - Tl	4 - Ts	5 - Si	6 - Vc	7 - Js.	8 - Hc	Seed Matl.
869	761	747	886	889	894	843	26960
489	453	444	502	499	508	482	11103
378	310	301	384	390	386	358	15851
261	147	157	284	289	288	228	6481
86	41	51	100	98	101	75	2615
175	105	107	185	190	189	158	3687
605	613	591	601	596	607	611	20479
401	407	394	400	398	408	408	8488
203	206	195	202	198	200	201	11984
7.3	7.4	7.4	7.4	7.4	7.4	7.4	7.1
240	177	147	202	209	214	212	
35.1	52.1	60.2	45.4	43.5	42.1	42.7	
1.87	4.2	3.2	3.7	2.0	3.0	2.2	
0.25	2.5	3.0	0.4	0.3	0.2	0.6	
278.765	278.197	278.373	278.505	277.248	278.277	278.439	
243.696	210.047	206.413	244.981	247.630	249.340	239.296	
35.069	68.150	71.960	33.524	29.618	28.937	43.143	
12.6	24.5	25.8	11.8	10.7	10.4	15.5	
16.0	27.4	28.7	15.5	14.4	13.9	18.8	
98.853	98.713	98.733	98.805	98.368	98.701	98.765	
73.272	40.529	43.270	78.656	80.771	80.468	64.878	
25.581	58.184	55.463	20.149	17.597	18.233	(38.142)	
26.4	59.0	56.4	20.4	17.9	18.5	38.6	
27.8	60.0	57.3	22.5	20.1	20.7	37.6	

eed material

Table 17 Sewage & Effluent Characteristics

Series - 250 gal./day - August 20 - September 23, 1947

2 - Re	3 - Tl	4 - Ts	5 - Si	6 - Vc	7 - Js	8 - Hc	9 - Jg
646	669	600	648	666	642	647	
421	420	409	428	436	422	424	
224	249	193	221	230	218	226	
125	131	73	122	146	109	127	
49	41	19	39	50	28	39	
89	91	53	83	96	80	88	
520	538	527	527	520	532	520	
385	378	388	388	386	390	385	
136	159	141	139	133	138	137	
7.4	7.4	7.4	7.5	7.5	7.4	7.4	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	263

#'s solids (sewage) added	278.018	278.765	278.197	278.373	278.5
#'s " (effluent)	194.823	243.696	210.047	206.413	244.9
#'s " removed	83.195	35.069	68.150	71.960	33.5
% T.S. reduction based on R.S. added (1)	29.9	12.6	24.5	25.8	
% T.S. " " " total " (2)	39.7	16.0	27.4	28.7	
#'s suspended (sewage) added	98.678	98.853	98.713	98.733	98.8
#'s " (effluent)	39.401	73.272	40.529	43.270	78.6
#'s " removed	59.277	25.581	58.184	55.463	20.1
% S.S. red. based on R.S. added	60.1	26.4	59.0	56.4	
% S.S. " " " total added	64.7	27.8	60.0	57.3	

(1) For the period June 10 - Aug 18, 1947
(2) For the period June 10 - Aug.18, 1947 - includes seed material

Table 17 Sewage & Effluent Characteristic

2nd Series - 250 gal./day - August 20 - September

Item	Raw	1 - J1	2 - Re	3 - T1	4 - Ts	5 -
Raw sewage added-gal.	7492.5					
T.S. - ppm.	821	609	646	669	600	64
T.S. ash-ppm.	463	418	421	420	409	42
T.S. vol.-ppm.	359	191	224	249	193	22
S.S.- ppm.	312	76	125	131	73	12
S.S. ash-ppm.	73	18	49	41	19	
S.S. vol.-ppm.	241	59	89	91	53	
Dis. Sol- ppm.	512	533	520	538	527	5
D.S. ash -ppm.	392	400	385	378	388	3
D.S. vol.-ppm.	120	133	136	159	141	1
pH	7.3	7.5	7.4	7.4	7.4	7.
B.O.D.-ppm.	368	148	172	169	146	1
Grease	-					
Sludge vol. cu. ft. (9/17)		19.5	2.5	8.6	7.5	
Scum vol. cu. ft. (9/17)			-	0.6	0.7	-
#'s solids sewage added		51.432	51.432	51.432	51.432	51.4
#'s solids (effluent)		37.903	40.346	41.828	37.580	40.5
#'s solids removed		13.529	11.086	9.604	13.852	10.9
% Red. T.S. based on R.S. added (1)		26.3	21.6	18.7	27.0	
% " T.S. " " total added (2)		37.7	16.8	26.1	28.5	
#'s Suspended (sewage) added		19.505	19.505	19.505	19.505	19.5
#'s " effluent		4.775	7.879	8.233	4.604	7.6
#'s " removed		14.730	11.626	11.282	14.901	11.8
% S.S. red. based on R.S. added (1)		75.5	59.6	57.9	76.5	
% S.S. " " " total added (2)		65.8	33.0	59.7	60.5	

(1) For the period Aug. 20 - Sept. 23, 1947
(2) For the period June 10 - Sept. 23, 1947 - includes seed material & added sludge

55.1	52.1	60.2	45.4	43.5	42.1	42.7
1.87	4.2	3.2	3.7	2.0	3.0	2.2
0.25	2.5	3.0	0.4	0.3	0.2	0.6
278.765	278.197	278.373	278.505	277.248	278.277	278.439
243.696	210.047	206.413	244.981	247.630	249.340	239.296
35.069	68.150	71.960	33.524	29.618	28.937	43.143
12.6	24.5	25.8	11.8	10.7	10.4	15.5
16.0	27.4	28.7	15.5	14.4	13.9	18.8
98.853	98.713	98.733	98.805	98.368	98.701	98.765
73.272	40.529	43.270	78.656	80.771	80.468	64.878
25.581	58.184	55.463	20.149	17.597	18.233	(38.142)
26.4	59.0	56.4	20.4	17.9	18.5	38.6
27.8	60.0	57.3	22.5	20.1	20.7	37.6

d material

able 17 Sewage & Effluent Characteristics

ries - 250 gal./day - August 20 - September 23, 1947

2 - Re	3 - Tl	4 - Ts	5 - Si	6 - Vc	7 - Js	8 - Hc	9 - Jg
646	669	600	648	666	642	647	
421	420	409	428	436	422	424	
224	249	193	221	230	218	226	
125	131	73	122	146	109	127	
49	41	19	39	50	28	39	
89	91	53	83	96	80	88	
520	538	527	527	520	532	520	
385	378	388	388	386	390	385	
136	159	141	139	133	138	137	
7.4	7.4	7.4	7.5	7.5	7.4	7.4	
172	169	146	162	163	183	183	263
2.5	8.6	7.5	5.2	3.3	5.1	3.3	4.0
-	0.6	0.7	-	-	0.2	-	0.6
51.432	51.432	51.432	51.432	51.432	51.432	51.432	
40.346	41.828	37.580	40.516	41.581	40.009	37.497	
11.086	9.604	13.852	10.916	9.851	11.432	13.935	
21.6	18.7	27.0	21.2	19.1	22.3	27.1	
16.8	26.1	28.5	16.3	14.9	15.1	20.0	
19.505	19.505	19.505	19.505	19.505	19.505	19.505	
7.879	8.233	4.604	7.662	9.123	6.765	7.940	
11.626	11.282	14.901	11.883	10.382	12.740	11.565	
59.6	57.9	76.5	61.0	53.3	65.3	59.3	
33.0	59.7	60.5	28.7	24.4	27.9	41.1	

eed material & added sludge

form in Table 17 . A study of the results indicate that suspended solids removals increased varying from 53.3 to 76.5 per cent. As will be noted, there is much less variation in removals between the tanks, than in the previous run. At this rate of feed, tank shape is apparently of less significance than for the higher rate of feed. Highest removals of suspended solids were obtained in the 4-chambered tank. For reasons not known to us, the 2-chambered tank did not show as high removals in this series as in the previous one. B.O.D. reductions were greater in this series ranging from 60.3 to 50.3 per cent with the highest reduction shown by the 4-chambered tank.

A mixture of approximately 200 gallons of septic tank sludge, obtained from tanks in the field and Imhoff tank sludge from the Glendale, Ohio, municipal plant, was added to each tank on September 29-30 and October 7-8 to build up these sludge volumes. Fresh raw sewage was added to each tank at the rate of 250 gallons per day during the period October 3 to November 8, 1947. This period is identified as the third series of operation.

During this period removals of suspended solids were much higher than in the two previous series, ranging from 49.1 to 88.0 per cent. The highest removals were shown by the 4 and 2-chambered tanks (88.0 and 83.0 per cent, respectively). The 2000 gallon Joint Committee tank indicated a removal of 83.5 per cent. The remaining tanks were closely grouped from 49.1 to 66.7 per cent. B.O.D. reductions were also higher during this run than previously, ranging from 64.0 to 81.6 per cent, with the highest reduction indicated by the 4-chambered tank. The results of operation of this series are summarized in Table 18.

The fourth series of operation began with the addition of about 300 gallons of sludge from field septic tanks on November 17 and 18. Fresh raw sewage at the rate of 250 gallons per day per tank has been added since that time. The

Table 10 - Sewage & Effluent Characteristics

3rd Series - October 3 - November 8, 1947 - 250 gals/day feed after additi

Item	Raw	Jl - 1	Re - 2	Tl - 3	Te - 4	Sl - 5
Sewage added-gal.	7577.5					
T.S.-ppm.	1034	667	808	687	648	756
T.S. ash-ppm.	544	461	537	488	460	517
T.S. vol.-ppm.	492	207	273	200	187	237
S.S.-ppm.	361	59	183	61	43	147
S.S. ash-ppm.	93	13	84	18	13	56
S.S. vol.-ppm.	267	45	99	44	32	90
D.S.-ppm.	674	609	626	627	604	609
D.S. ash -ppm.	450	446	452	470	448	463
D.S. vol.-ppm.	222	162	173	157	157	147
pH	7.5	7.5	7.5	7.5	7.5	7.5
B.O.D.-ppm.	365	94	131	85	67	87
Grease-ppm.	105	10	13	8	12	19
Sludge vol.-cu. ft. - (11/6)		33.6	18.9	20.6	24.0	21
Scum vol.-cu. ft.	-	-	-	-	-	-
#'s solids (sewage) added		65.371	65.371	65.371	65.371	65.371
#'s solids effluent		42.205	51.067	43.432	40.914	44.721
#'s solids removed		23.166	14.304	21.939	24.457	20.650
% T.S. red. based on R.S. added (1)		35.4	21.9	33.6	37.5	31
% T.S. " " " total added (2)		45.8	29.3	37.8	40.0	28
#'s S.S. (sewage) added		22.751	22.751	22.751	22.751	22.751
#'s S.S. effluent		3.762	11.568	3.869	2.733	9.268
#'S S.S. removed		18.989	11.183	18.882	20.018	13.483
% S.S. red. based on R.S. added (1)		83.5	49.1	83.0	88.0	59
% S.S. " " " total added (2)		77.2	54.9	74.5	75.6	51

(1) For the period Oct. 3 - Nov. 8, 1947
(2) For the period June 10 - Nov. 8, 1947 - includes seed material & added sludge

Table 10 Sewage & Effluent Characteristics

vember 8, 1947 - 250 gals/day feed after addition of sludge to build up volume.

- 1	Re - 2	Tl - 3	Te - 4	Si - 5	Vc - 6	Js - 7	Hc - 8	Jk - 9
667	808	687	648	756	724	716	711	
461	537	488	460	517	489	484	481	
207	273	200	187	237	236	231	228	
59	183	61	43	147	144	123	120	
13	84	18	13	56	56	46	43	
45	99	44	32	90	88	75	78	
609	626	627	604	609	581	594	590	
446	452	470	448	463	430	438	439	
162	173	157	157	147	147	155	152	
7.5	7.5	7.5	7.5	7.5	7.6	7.5	7.5	
94	131	85	67	87	85	100	102	93
10	13	8	12	19	21	22	29	28
33.6	18.9	20.6	24.0	21.5	18.4	29.4(?)	12.4	15.2
-	-	-	-	-	-	-	-	-
.371	65.371	65.371	65.371	65.371	65.371	65.371	65.371	
.205	51.067	43.432	40.914	44.721	45.732	45.275	44.876	
.166	14.304	21.939	24.457	20.650	19.639	20.096	20.495	
35.4	21.9	33.6	37.5	31.6	30.1	30.8	31.4	
45.8	29.3	37.8	40.0	28.5	28.8	29.2	32.7	
.751	22.751	22.751	22.751	22.751	22.751	22.751	22.751	
.762	11.568	3.869	2.733	9.268	9.139	7.831	7.596	
.989	11.183	18.882	20.018	13.483	13.612	14.920	15.155	
83.5	49.1	83.0	88.0	59.2	59.9	65.7	66.7	
77.2	54.9	74.5	75.6	51.2	51.6	53.9	61.4	

includes seed material & added sludge

difference in removals between tanks has decreased with all tanks showing higher removals in suspended solids than previously. Highest removals were again shown by the 4-chambered tank. In fact, in this series, removals for most tanks were approximately equal to or higher than in the 2000 gallon Joint Committee tank. B.C.D. reductions were not quite as high as in the previous run, ranging from 69.8 to 76.5 per cent.

During this period a single chambered tank (C1) and a two-chambered tank (C2) were added to obtain information relative to the removal effected by each chamber of the multi-chambered tanks. As previously, each chamber was seeded with 10 per cent septic tank sludge on a volumetric basis. Removals obtained during the period of December 8, 1947, to January 4, 1948, are tabulated in Table 19 and compared with the removals in Tank No. 4, the 4-chambered tank.

Table 19 Effect of Adding Compartments

Tank No.	lbs. of Suspended Solids Removed	% Removal Based on R.S.	B.O.D. in ppm.(2)	% B.O.D. Red. Based on R.S.
12-C1	23.333	70.0	265	47.5
13-C2	27.853	83.5	229	54.5
4-Ts	30.827	92.5	133	73.6
R.S.(3)	33.352 (1)		504	

(1) lbs. of Suspended Solids added.
(2) Results of 4-days test
(3) R.S. - raw sewage

Discussion - As will be seen in Table 14 , the volume of scum in all tanks disappeared after a certain period of operation, with the exception of the Joint Committee 2000 gallon tank which never had any scum. The reason for this loss of scum is not explained. However, several ideas are advanced which may serve to explain the reason for this in part. Scum was present during the period of highest feed, which may be considered as the period of greatest turbulence in the tank. The liquid level in the tanks fluctuated most widely during these high dosage rates. Yet there was scum. It was thought at first that perhaps there was a reduction in scum because of the higher temperatures that prevailed during the summer months, but during the winter months, if temperature was responsible for loss of scum, the scum should reappear. There still is no scum. One other possible explanation that has occured to us is that the scum has broken up and settled due to the overturning of the tank contents. This phenomenon occurs at relatively frequent intervals (perhaps several times daily) and would tend to keep any scum which might appear on the surface very wet and easily broken up so that it would settle with the sludge particles to which it may have adhered.

The overturning of the tank contents (sludge) may be responsible for the very high removals of suspended solids obtained. The fluid or flocculent sludge, in settling, provides a mass of tiny particles acting as a nucleus for fresh material by adhesion, thus facilitating sedimentation. Such mixing is beneficial in bringing into contact with the fresh material a large mass of digested or partially digested solid matter, which may be conducive to higher efficiencies in tank operation.

Percentage removals of suspended solids based on raw sewage solids added, tanks 1 through 8, are presented for comparison in Table 20.

Table 20 Per cent Removal Suspended Solids

	1st Series 6/10-8/18 (500 g.p.d.)	2nd Series 8/20-9/23 (250 g.p.d.)	3rd Series 10/3-11/8 (250 g.p.d.)	4th Series 11/24-1/18 (250 g.p.d.)
1-Jl	60.1	75.5	83.5	83.1
2-Re	26.4	59.6	49.1	76.8
3-Tl	59.0	57.9	83.0	86.3
4-Ts	56.4	76.5	88.0	89.6
5-Si	20.4	61.0	59.2	81.7
6-Vc	17.9	53.3	59.9	78.9
7-Js	18.5	65.3	65.7	76.7
8-Hc	38.6	59.3	66.7	79.4

It will be noted from Table 20 that under the feed and sludge loading conditions previously mentioned, the two multi-chambered tanks showed an almost consistent superiority in suspended solids removal over the single compartmented tanks, all in the 500 gallon capacity range. Also that they were in the range of removals from the 2000 gallon J.C. tank. However, the latter, aside from initial seeding sludge, received only the same amounts of the accelerated sludge additions as the 500 gallon tanks, resulting in a smaller percentage of tank space occupied by sludge, and the results of proportionately large sludge volumes in this tank have yet to be determined.

Considering the single compartment tanks in the 500 gallon capacity range (nos. 2,5,6,7 and 8), it will be seen from Table 20 that the influence of tank shape, so far as suspended solids removal is concerned, tends to become less and less as the doseage rate was reduced and as sludge accumulations in the tanks were increased by the addition of sludge.

Efficiency of suspended solids removal increased with increasing sludge accumulation throughout the tests thus far. Operation will be continued with increased sludge accumulations until the peak, and subsequent falling off in efficiency, is observed. The small single and double chambered tanks showed relatively high removals when fed at the same rate as the other tanks. The results were shown previously in Table 19.

Table 21 indicates the percentage of tank volume occupied by sludge January 5, 1948, together with the number of years accumulation represented, as determined from the field data.

Table 21 . Apparent Tank Volume Occupied by Sludge

Tank	Percent of Volume Occupied by Sludge Jan. 5, 1948	Years of Accumulation Based on Sludge as of Jan. 5, 1848 *
J1	20.4	9 +
Re	32.2	3.9
T1 (total)	36.9	7.0
Chamber 1	49.8	
Chamber 2	24.0	
Ts (total)	35.5	9 +
Chamber 1	57.2	
Chamber 2	46.3	
Chamber 3	26.7	
Chamber 4	11.8	
Si	40.3	7.7
Vc	45.2	7.2
Js	37.5	6.9
Hc	30.5	3.2
Jg	37.7	6.9

* Based on data contained in curve labeled "Mean Accumulation - Scum & Sludge - 153 inspections - U.S.P.H.S.-H.H.F.A. Project" and assuming 4 persons contributing to each tank.

port) are based on grab samples collected at various times during successive days.

Table 22 Raw Sewage Characteristics

Determination	Parts per million			
	Series 1 (1)	Series 2 (1)	Series 3 (1)	Series 4 (1)
	June 10-Aug. 18	Aug. 20-Sept. 23	Oct. 3-Nov. 8	Nov. 17-Jan. 4
Total solids	986	821	1034	1340
Ash	504	463	544	654
Volatile	482	359	492	686
Suspended Solids	348	312	361	636
Ash	77	73	93	134
Volatile	271	241	267	502
Dissolved Solids	638	512	674	703
Ash	427	392	450	519
Volatile	212	120	222	184
Alkalinity	240			
Grease			105	
B.O.D.	370	368	365	478
pH	7.3	7.3	7.5	7.4

(1) Weighted averages.

Analytical Methods, Organic carbon of soils. - The procedure used was that proposed by Prof. A. L. Prince, Soils Department, N. J. Agr. Experiment Station, New Brunswick, New Jersey. In essence the method consisted of taking a portion of the soil under test, adding 10 ml. of approximately 0.4 N chromic acid, boiling moderately with a funnel condenser for 5 minutes, cooling, diluting with 250 ml. of water, acidifying with 3.5 ml of sulfuric acid and titrating against ferrous ammonium sulfate, using 3 drops of ortho-phenanthroline indicator. A parallel blank sample is run using organic carbon-free sand. From the number of ml. of ferrous ammonium sulfate it is possible to compute the per cent carbon in the sample.

Soil Absorption Studies - Percolation Test, Soil Analysis - Soil percolation tests have been made in the Cincinnati area on various types of soil, using the standard one-foot-square percolation test, a one-foot-square confined box, and a ten-inch diameter cylinder 18 inches long. These preliminary studies indicated that after correction for the greater seepage area in the unconfined test the results obtained were relatively similar. On the basis of these results the 10-inch-diameter cylinder was adopted for making percolation tests in the field along with the standard unconfined one-foot-square test.

Mechanical analyses (sieve and hydrometer tests) and tests for the plastic limit were made on samples collected in the field from areas where percolation tests were made in an attempt to correlate these laboratory tests with the percolation properties of soils. In our three hundred mechanical analyses with moisture contents and plastic limits it has not been possible to demonstrate any correlation with field percolation data. No liquid limits data is available at this time.

Additional tests were made to try to show differences in the physical and chemical properties of soils taken from the tile field itself, beneath or adjacent to the tile line and soils taken further away from the tile line, but these too failed to show any important differences. Organic carbon, volatile solids content and pH determinations were made on approximately 40 pairs of samples, one of which was from the tile area and the other from an undisturbed area.

An attempt will be made to correlate the coefficient of permeability to the percolation test in the field. To determine this, the coefficient of permeability will be computed for the percolation test in place in terms of the thickness of the layer through which percolation takes place. This depth cannot be measured directly in the field. The soil sample is then removed with approximately three to four inches of soil still in place in the bottom of the percolation cylinder and the test is repeated above ground in the laboratory. From a study of the two results (the value based on the field determination and the value obtained in the laboratory), it may be possible to compute the effective depth of percolation. For dense or tight soils it will be necessary to construct a variable head permeameter, since the rate of percolation will be very slow.

The apparatus for making the test in the field may have to be modified to determine the percolation that takes place in the horizontal as well as the vertical directions. For a porous soil percolation will take place essentially in a vertical direction. As the soil becomes more impervious lateral percolation becomes more pronounced.

The soil laboratory tests outlined previously will be run on samples and collected in the field in an undisturbed state under control conditions. To do this the technique of sample collecting will be developed here in Cincinnati and instructions prepared for the field crew after preliminary tests have been made indicating the value of these procedures.

Clogging Characteristics - Samples of sewage after 24-hours settling were passed through a glass walled filter 3 inches in diameter which had been filled with sand to a depth of 12 inches. Dosage rates varied from 1260 to 4600 ml. per day. During the period March 31 to April 30, 86.21 liters of settled sewage passed through the filter. Assuming a maximum loading of 5.3 gallons per square foot per day (corresponding to a percolation test result of one inch fall per minute for seepage pits), this would be equivalent to operating the unit for approximately 2.6 years. The filter clogged several days later. The long period of operation may be due in part to the fact that the filter was operated intermittently, dosing for 4 days and resting for 3 days.

A summary of the laboratory data obtained in conjunction with the above study has been given previously. (See Table X on page 52 of the 1st Progress

Report).

The above test was repeated using twelve 4-inch diameter drain spouts for the filters and adding the effluent from each tank to the filter. Sand for these filters was obtained from septic tank-sand filter installations in the vicinity of Cincinnati. The filters contained three inches of graded gravel at the bottom supporting a 12-inch layer of sand. Above the sand there was a 1 inch layer of fine gravel to assist in spreading the effluent as it was allowed to drip onto the filter. Effluent was added 8 times daily in proportion to the feed schedule employed in operating the septic tanks in the greenhouse, and the application rate was set at 200,000 gallons per acre per day. In addition to the normal effluents from the tanks, two filters received an application of filtered effluent from the two Joint Committee tanks (2,000 gallon & 500 gallon). These were run to determine what effect suspended solids would have on the length of filter run. Most filters clogged after several days of operatioh and on dismantling were found to contain much fine material and mud balls. To overcome these difficulties in subsequent runs, the filter sand was thoroughly dried and all material passing the 200-mesh sieve discarded. In addition, all sand and gravel was ignited to remove organic material. The test being repeated and after 3 days of operation during which 4155 ml. of raw sewage and effluent have been added, the filter receiving raw sewage shows evidence of ponding on top of the filter surface. Dosage is at the rate of 198,000 gallons/acre/day.

The effect of bacterial on clogging has been investigated to some extent and will be discussed in a later section.

Tile Line Studies - Grades, Joint Spacing - The study of the behavior of fluids flowing through open joints in a tile field under various conditions of joint size, shape of tile line, volume of fluid, etc., was initiated.

A stand long enough to accomodate 10 lengths of regular one foot 4-inch field tile was set up in such a way that effluent could be collected at each joint. It was also possible to vary the slope.

To date runs have been made at flow rates varying from 1.15 to 26.7 gallons per minute at slopes of 0.0, 1.0, 2.0 and 4.0 per cent, with tile sections placed end to end. Even when so placed, invert joint spaces varied from 0.3 to 5.0 mm.

Attempts were made to correlate discharges through the joints with rates of flow. For this purpose the discharge was assumed to be a function of the joint openings. The quantities of liquid discharging through each joint were divided by the number of "Joint Units" in the joints. The "Joint Units" were determined by dividing the actual joint space by the minimum joint space which was found to be 0.3 mm. For example, if the joint space was 0.9 mm in length, the number of joint units would be 0.9 divided by 0.3 or 3. This value divided into the actual discharge through the joint would give the discharge per joint unit. Joint discharge, even after correction by this method were very variable, due to the differences in invert elevation (up to 4mm. or more) between two adjacent tile ends. To correct for this, it is planned to run additional studies on long sections of pipe with the joints cut in before hand.

Tile Lines - Six 50-foot tile lines were laid in the subsurface soil behind the greenhouse. Their characteristics are shown in the following Table 23. The lines were laid from 18-24 inches below the ground surface with tile ends butted, and each line is provided with an effluent standpipe to permit the measurement of the liquid level. No fluid has been observed in the effluent end of tile lines at any time during the feeding experiment. The lines are fed eight times daily, in an amount equivalent to the respective feed to the tanks in the greenhouse. Effluent from the vertical cylindrical tank has been used for this purpose because originally, this tank discharged an effluent which was higher in suspended matter. The amount of effluent added to date is included in the table. The daily additions are based on computing from percolation test data obtained at tile line level.

Table 23 Tile Line Characteristics

Line	Width of Trench	Grade	Daily Feed	Remarks	Volume sewage added to 12/31/47
A	18 inches	2.0%	30 gal.	Sod cover over trench	2594.0
B	18 inches	0.0%	30 gal.	Control -sod cover	2285.4
C	18 inches	0.0%	30 gal.	Tree root study	1818.0
D	24 inches	0.0%	37.5 gal.	Sod cover	2313.9
E	18 inches	1.0%	30 gal.	Sod cover	1694.7
F	18 inches	0.0%	30 gal.	No sod cover over trench	1664.7

Garbage - A 500-gallon Joint Committee tank has been added to the present series of tanks and has been under observation since August 19, 1947. It has received in addition to the sewage load added to the other tanks, an amount of garbage contributed by a family of two (originally three) living on the Station site. The results at present show removals equal to or greater than in the comparable 500-gallon Joint Committee tank.

Special Studies - Household Zeolite Softening - It has been indicated in the First Progress Report that the addition of regeneration liquor from Zeolite Softener will have no deleterious action on septic tanks unless added in excessive quantities. However, the ions contained in such liquor may be detrimental to drainage operation of the tile field. Special studies are being planned to determine if sodium, calcium and magnesium salts increase clogging in the tile field area.

Volume of Seed Material to be Used - In an attempt to answer the question, "How much digested sludge should be added to a digestion (septic) tank for seed purposes?", graduated quantities of digested sludge ranging from one-half to 20 per cent were added to sewage as seed material. Data based on rate of gas production and total volume of gas indicated (in the experimental set-up) that less than 5 per cent of digested sludge was insufficient for seed purposes and that 10 per cent is a satisfactory quantity. Gas production was slightly greater with 20 per cent seed material. Probably sludge for seeding in amount equal to five per cent of tank volume is the most practical quantity since it gives reasonably rapid digestion and takes up a minimum volume of space in the tank.

Yeast Experiments - The addition of yeast alone to raw sewage in amounts up to 32 ounces per 500 gallons of sewage as seeding material for anaerobic fermentation was found unsatisfactory. No gas was produced in any of the sewage flasks seeded with the yeast, while approximately 3000 ml. of gas was produced in the control sewage flask seeded with 10 per cent digested sludge.

A later series of experiments in which increments of yeast were added to flasks containing raw sewage and digested sewage sludge indicated that more gas was produced in those flasks containing all three ingredients (i.e. sewage digested sludge and yeast) than those containing only sewage sludge and raw sewage sludge.

Grease - Laboratory determinations were made of the grease contents of the raw sewage and the effluents from the various tanks. High removals, ranging from 72.4 to 92.4 per cent were indicated by the tanks. This would lead us to conclude that grease traps need not be interjected between the house and septic tank. This avoids the difficulty of providing proper maintenance to the grease trap, and eliminates the difficulties inherent with the direct discharge of grease into the tile field from poorly maintanined units.

Bacteriological - Studies have been made of the bacterial occlusion of sand filters. Using a modified Sedgewick-Rofter funnel, experimental sand filters were prepared containing sand which passed through the 28 mesh sieve and was retained on the 48 mesh sieve (0.59 to 0.297 min.). Pure cultures of organisms, effluent and sterile media were fed to the filters by means of a constant head siphon, and at periodic intervals the rate of flow through the filter was determined. In this way 16 organisms, isolated from septic tank effluent, were tested and the effective and ineffective cloggers in the group determined. As will be seen in the figures some of the strains showed marked clogging characteristics when dosed at the high rates of 4.75 and 2.4 M.G.A.D.

In a second series, two effective cloggers and septic tank effluent were inoculated in sterile media in duplicate. One of each duplicate was killed by the addition of minimal doses of formaline and all six systems were compared for clogging effect. The results, for the three systems studied, indicated that the clogging ability of these organisms was virtually destroyed by death of the organisms.

To study the effect of the rate of application on clogging, test organism No. 33, an effective clogger at the high rates, was employed. This organism was applied to the filters at rates equivalent to 0.5, 1.0, 1.5, and 4.75 M.G.A.D. As shown in Figure 28 , the lower the rate of application the less tendency there is for clogging during the time of test.

In another series, simultaneous plate counts were made on the influent and effluent substrates to study the effect of filtration on bacterial numbers. It was found that bacterial numbers increased during passage through the filters.

The test organisms were isolated in pure culture from routine plate counts of septic tank effluents under study. Following isolation of the organism, it

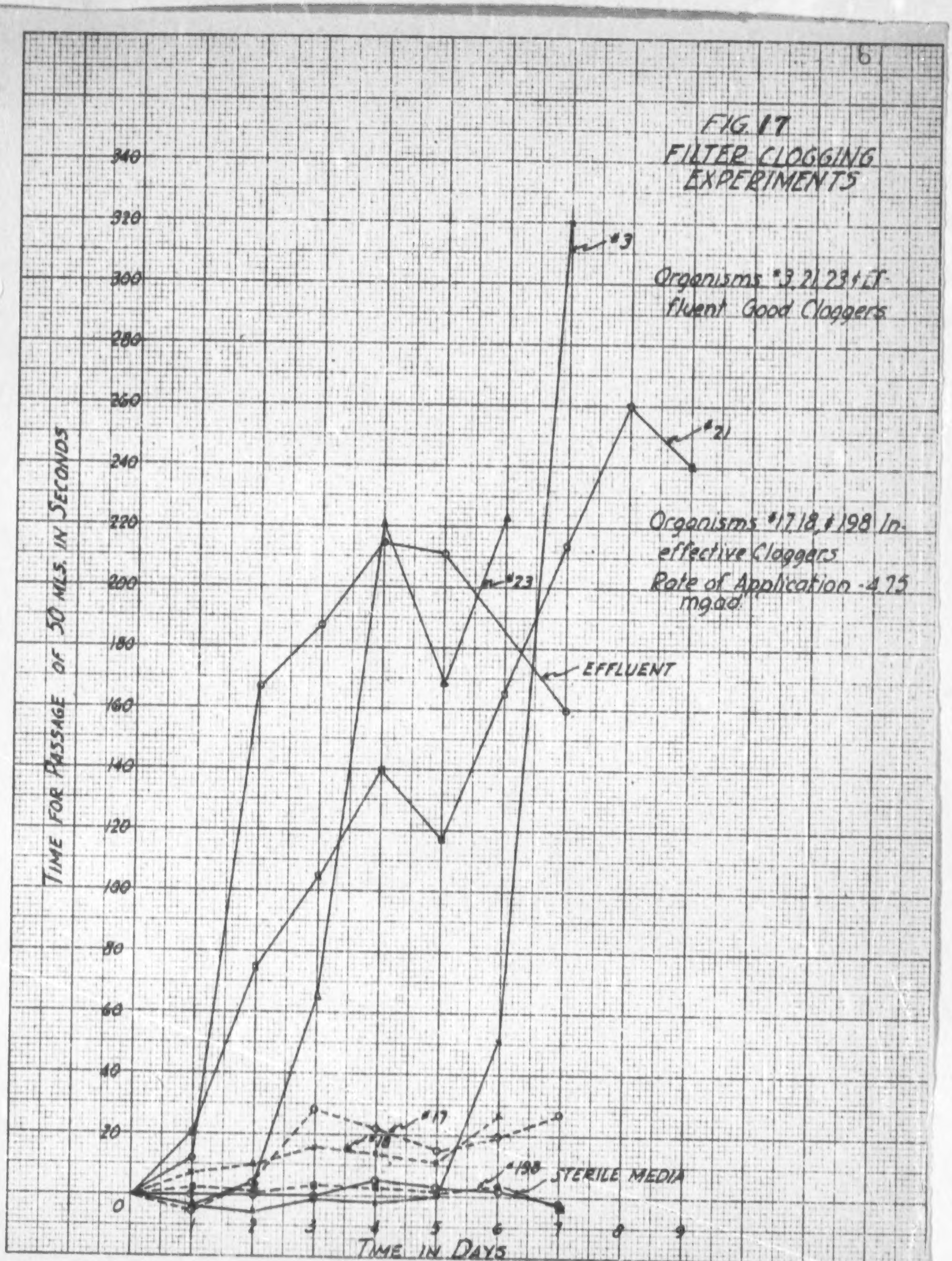


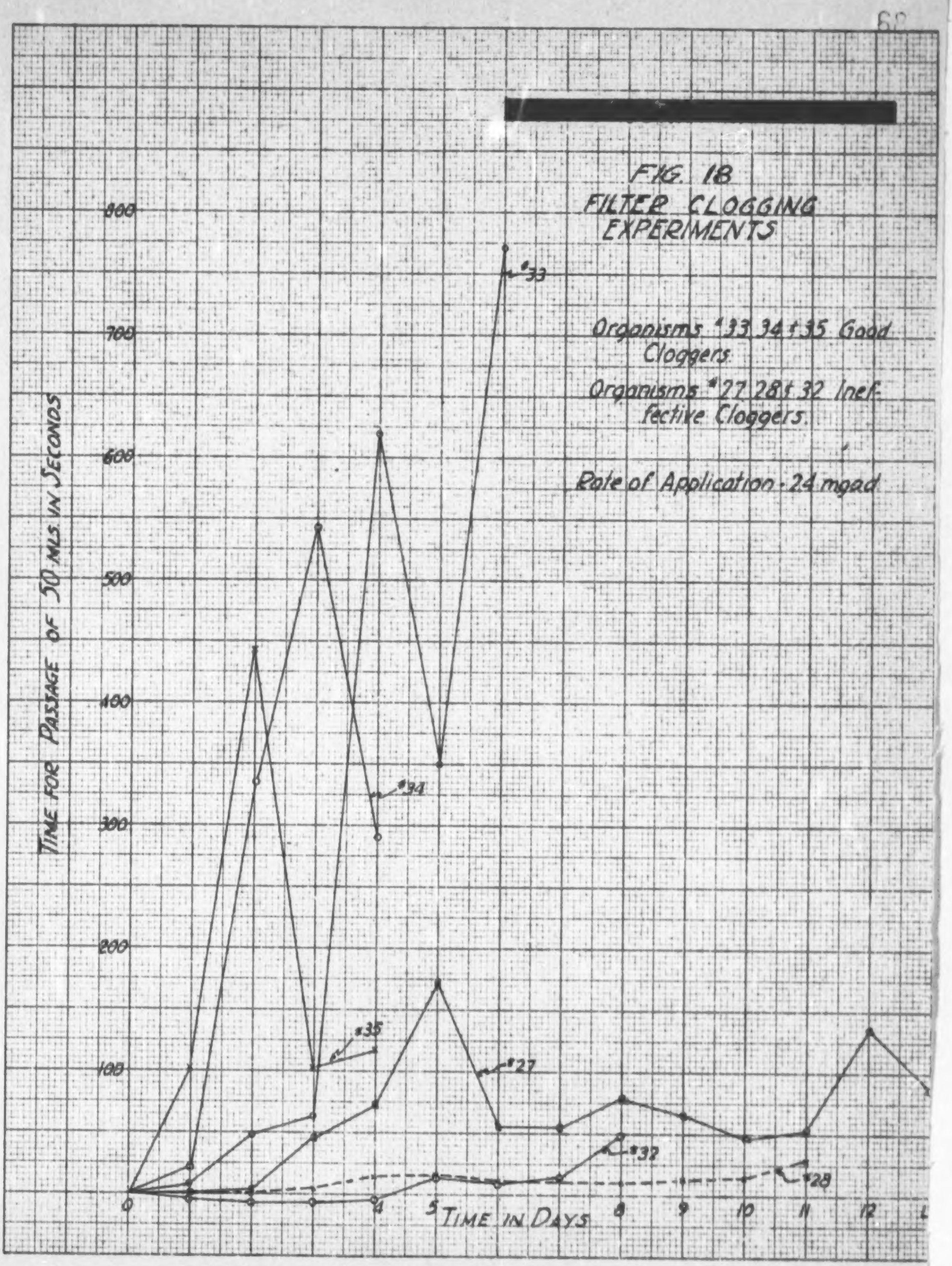
FIG. 17
FILTER CLOGGING
EXPERIMENTS

Organisms #3, 21, 23 & Ef-
fluent Good Cloggers

Organisms #17, 18, & 198 In-
effective Cloggers

Rate of Application - 4.75
mgad

KEUFFEL & ESSER CO., N. Y. NO. 359-12
20 × 20 to the half inch, 10th lines heavy.
MADE IN U. S. A.



[redacted]

FIG. 18
FILTER CLOGGING
EXPERIMENTS

Organisms #33 34 & 35 Good Cloggers.

Organisms #27 28 & 32 Ineffective Cloggers.

Rate of Application - 24 mgad

10 × 10 to the half inch, 10th lines heavy.
MADE IN U.S.A.

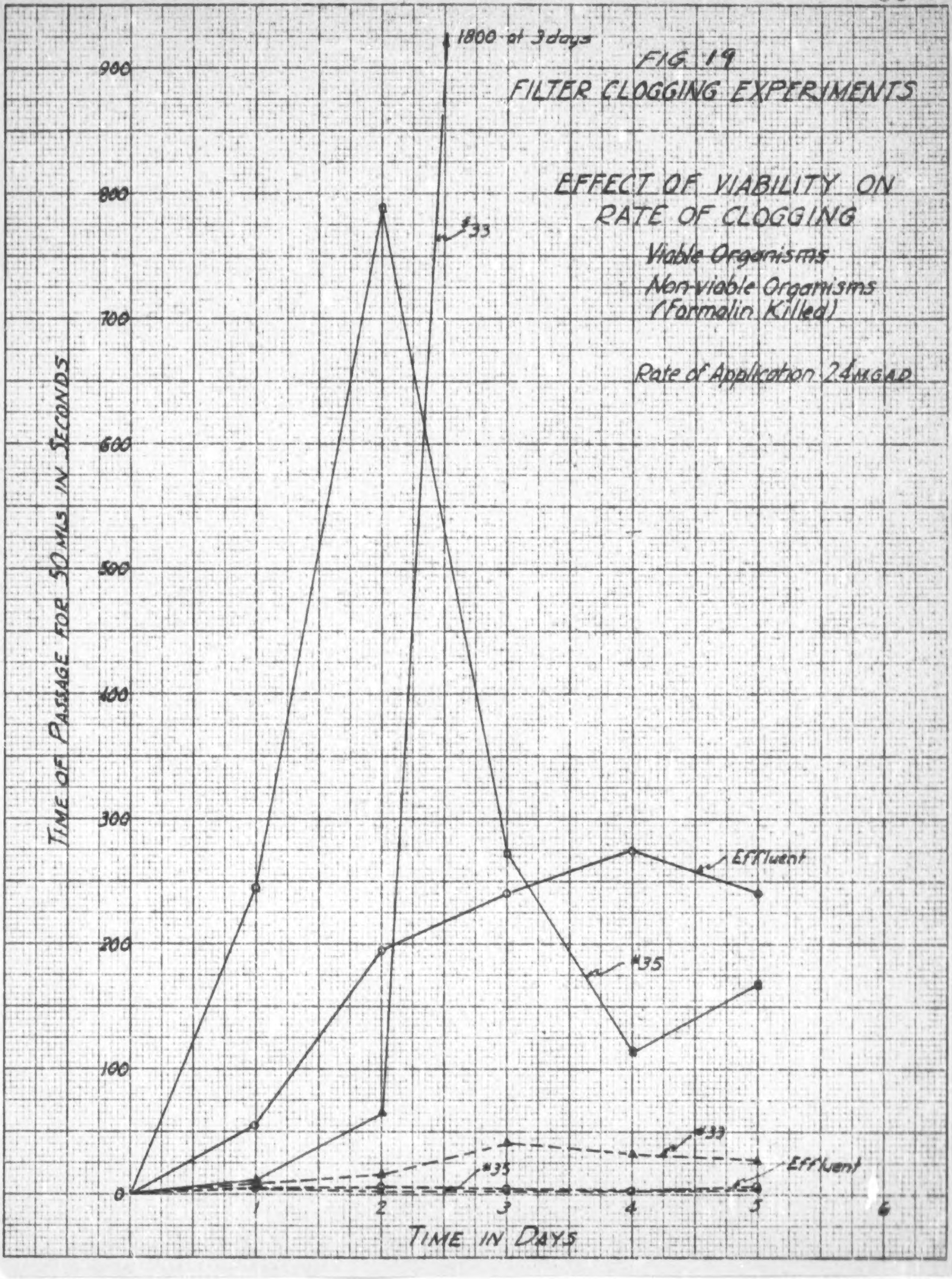


FIG. 19

FILTER CLOGGING EXPERIMENTS

EFFECT OF VIABILITY ON RATE OF CLOGGING

Viable Organisms

Non-viable Organisms (Formalin Killed)

Rate of Application 24 MGAD

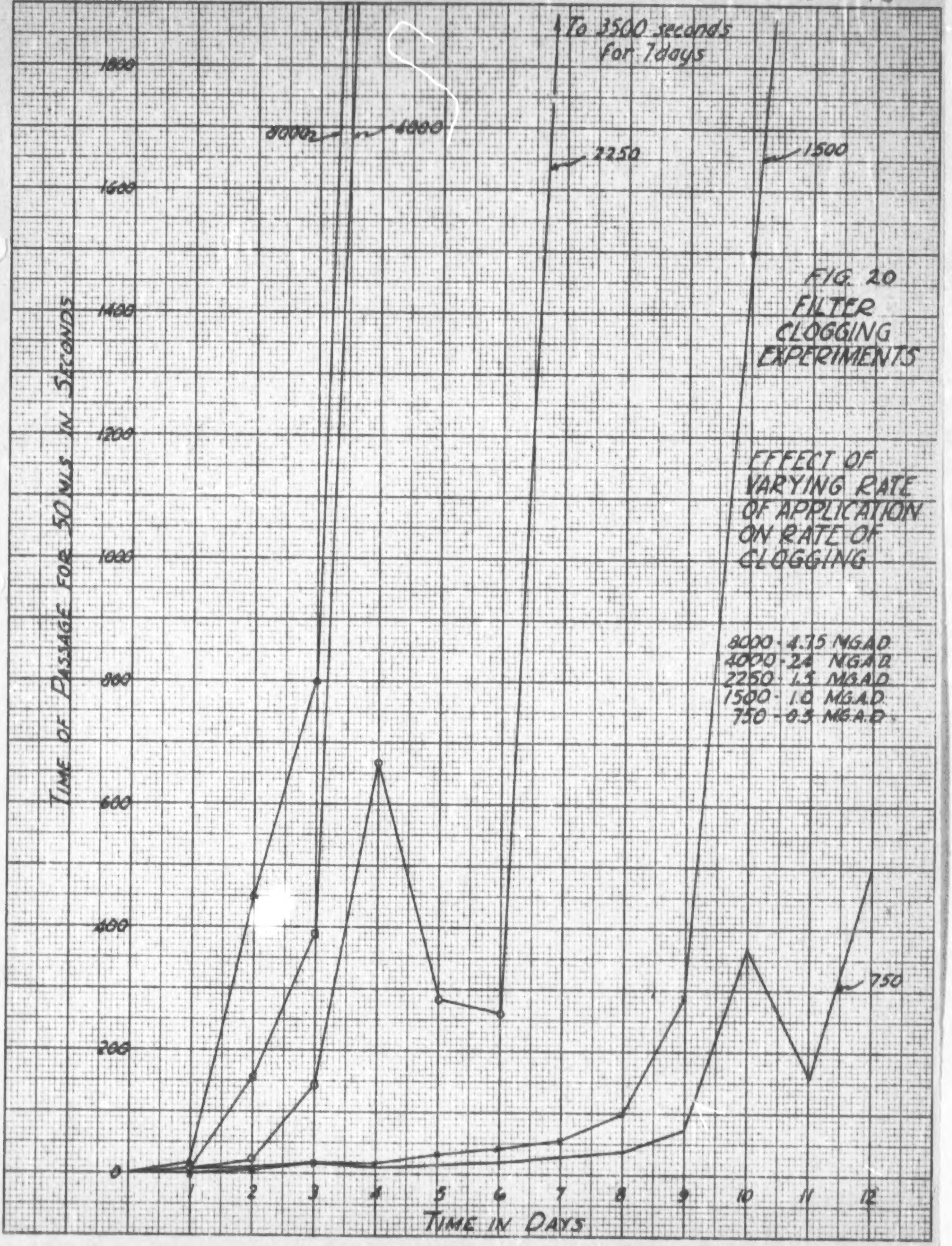


FIG. 20
FILTER
CLOGGING
EXPERIMENTS

EFFECT OF
VARYING RATE
OF APPLICATION
ON RATE OF
CLOGGING

was examined for the usual physical and biochemical characteristics. Thirty organisms were isolated and studied culturally. Of these 16, as reported previously, were studied for their effect on clogging.

From time to time during the investigation estimates were made of the total numbers of bacteria and the coliform counts in the raw sewage and tank effluents. These results are summarized in Table 24 along with the indicated percentage reduction. Bacterial numbers seem to be considerably higher in the fourth series than in the previous three series and bacterial removals are not as great. The sewage fed to the tanks, however, during the 4th series is considerably stronger than the sewage fed previously.

Table 24 Bacte

	1st Series **				2nd Series **		
Tank No.	Total Count (1) x 10^6	% Red. (2)	Coliform (3) x 10^5	% Red. (2)	T.C. (1) x 10^6	% Red. (2)	Coli x
Raw	7.75		4.03		13.11		4
J1	1.05	86.4	0.60	85.1	1.89	85.6	0
Re	1.69	78.2	1.59	60.6	1.85	85.9	0
Tl	1.47	81.0	1.51	62.6	1.07	91.8	0
Ts	0.97	87.5	1.69	58.1	0.99	92.5	0
Si	1.46	81.2	1.13	72.0	1.76	86.6	0
Vc	1.73	77.7	1.90	52.9	1.90	85.5	1
Js	1.60	79.4	1.39	65.5	2.52	80.8	2
Hc	1.59	79.5	1.60	60.4	2.13	83.8	2
Jg					1.97	85.0	1
Xr					1.28	90.2	1
Xl					1.38	89.5	1
C1							
C2							

* Geometrical mean

** 1st series - 7/14-8/19/47; 2nd series 9/8-9/23; 3rd series 10/21-11/10; & 4th series 11/

(1) Agar 37°C for 48 hours. 24 hour counts were reported prior to July 22.

(2) Based on numbers of organisms in raw sewage sample.

(3) M.P.N. of organisms at 37°C. Presumptive test used.

Table 24 Bacteriological Results *

	2nd Series **				3rd Series **				
ed. (2)	T.C. (1) x 10^6	% Red. (2)	Coli. (3) x 10^5	% Red. (2)	T.C. (1) x 10^6	% Red. (2)	Coli. (3) x 10^5	% Red. (2)	T
	13.11		4.20		11.16		5.07		
5.1	1.89	85.6	0.96	77.1	1.00	91.0	0.83	83.6	
0.6	1.85	85.9	0.74	82.4	1.39	87.5	2.37	53.2	
2.6	1.07	91.8	0.56	86.7	1.33	88.1	1.14	77.5	
8.1	0.99	92.5	0.75	82.1	1.02	90.9	1.50	70.4	
2.0	1.76	86.6	0.79	81.2	1.40	87.5	1.88	62.9	
2.9	1.90	85.5	1.17	72.1	1.37	87.7	1.54	69.6	
5.5	2.52	80.8	2.06	51.0	1.30	88.3	1.24	75.5	
0.4	2.13	83.8	2.68	36.2	1.37	87.7	2.22	56.1	
	1.97	85.0	1.28	53.1	0.77	93.1	1.27	74.9	
	1.28	90.2	1.88	55.2	0.80	92.8	0.63	87.6	
	1.38	89.5	1.46	65.2	0.88	82.1	1.24	75.5	

rd series 10/21-11/10; & 4th series 11/18-12/16/1947
ted prior to July 22.
e.
d.

3rd Series **				4th Series **			
.C. (1) x 10^6	% Red. (2)	Coli. (3) x 10^5	% Red. (2)	T.C. (1) x 10^6	% Red. (2)	Coli. (3) x 10^5	% Red. (2)
11.16		5.07		43.39		19.82	
1.00	91.0	0.83	83.6	5.30	87.8	5.54	72.0
1.39	87.5	2.37	53.2	9.64	77.8	11.71	40.9
1.33	88.1	1.14	77.5	8.95	79.4	26.15	Increase
1.02	90.9	1.50	70.4	7.79	82.0	14.24	28.2
1.40	87.5	1.88	62.9	9.51	78.1	11.30	43.0
1.37	87.7	1.54	69.6	11.99	72.4	17.79	10.2
1.30	88.3	1.24	75.5	9.47	78.2	15.00	24.3
1.37	87.7	2.22	56.1	9.43	78.3	20.52	Increase
0.77	93.1	1.27	74.9	6.36	85.3	12.52	36.9
0.80	92.8	0.63	87.6				
0.88	82.1	1.24	75.5				
				26.37	28.6	52.99	Increase
				18.13	50.9	12.20	51.0

4. Locate, construct, or otherwise secure at properly selected field locations and operate, under normal conditions tanks of some flexibility for trials and pilot studies.

5. Locate, construct, or otherwise secure at properly selected field locations and operate subsurface systems on experimental basis, including experimental seepage test holes, trenches, tile lines, and complete subsurface installations.

Progress on these topics is reported in detail under Item No. 3. As previously indicated operation of a battery of tanks at the Laboratory was undertaken in lieu of tanks in the field because of inability to locate a suitable central location and the difficulties involved in the control, sampling and interpretation of results on various tanks at scattered locations, subject to variation in individual households. It is expected to fortify the controlled findings at the Laboratory with sampling and gaging studies on selected installations in the field.

Progress on studies of tile line hydraulics, percolation tests and absorption lines is reported under Item No. 3 in this and the First Report. Additional absorption line installations at the Laboratory grounds are planned for Spring.

Negotiation for installation of a Joint Committee type tank and absorption system in the field were unproductive of a location free of compromising factors or side difficulties of various sorts. It is believed that the sampling and gaging program can be oriented to cover this type of installation and serve the control purposes intended.

6. Initiate sampling, gauging, and testing of several installations representative of current practices.

Sampling & Gaging:

Four field septic tank installations have been checked for various intervals of time and effluent flows (both rates and quantities) have been recorded. Samples were collected and composited automatically with each discharge of the gaging device. Typical charts showing hourly flow variations are included in the Appendix.

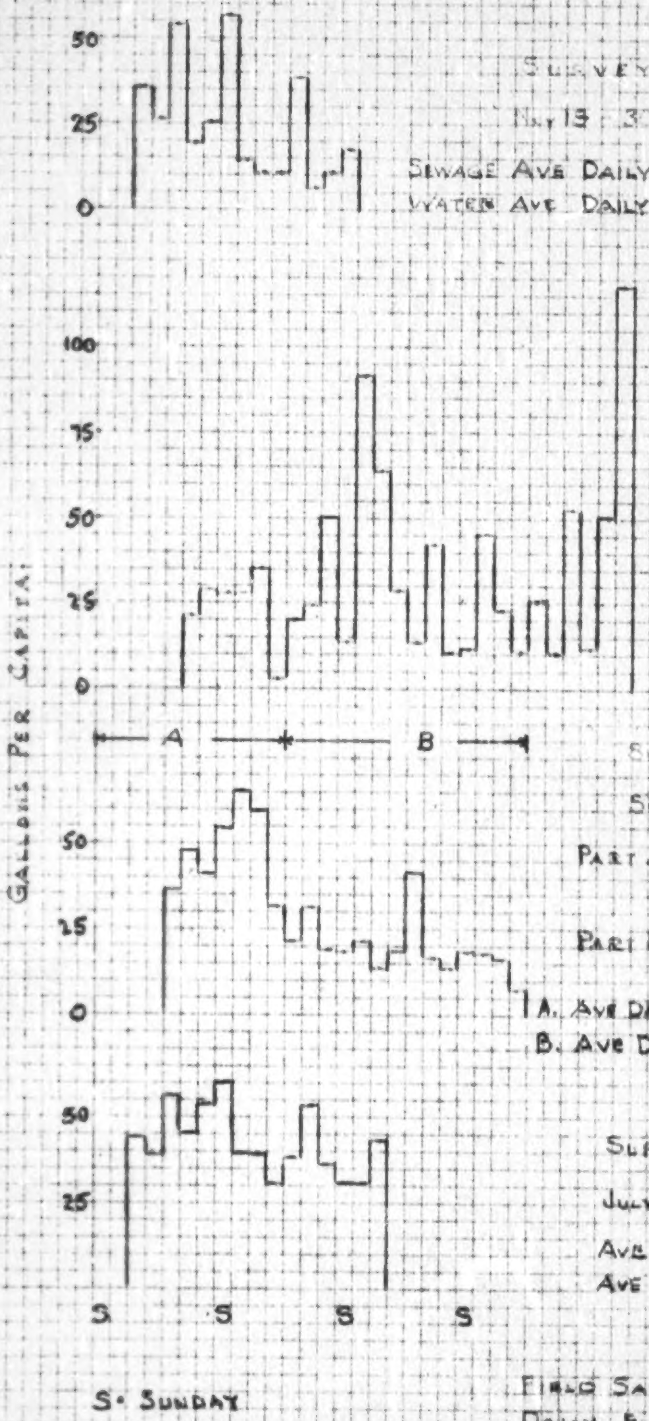
In the first study, the sampling and gaging unit was installed on the effluent line of a privately owned 900 gallon rectangular concrete single chambered septic tank serving a 3 bedroom, 4-person home. The tank, approved by the Hamilton County (Ohio) Health Department, measures 73 inches x 41 inches x 69 inches water depth and is equipped with tee inlet and outlet fixtures.

After two weeks of operation, the unit was moved to another location where a 750-gallon rectangular concrete single-chambered septic tank served a 2-bedroom, 3-person home. The tank is 74 inches long, x 39 inches wide and has a 60 inch water depth with tee inlet and outlet fixtures.

Upon completion of the second study, the unit was moved to a third site equipped with a 700 gallon rectangular concrete tank serving a 2-bedroom, 3-person house. The tank is 61 inches long, 47 inches wide, has a water depth of 56 inches and is provided with tee inlet and outlet fixtures.

The sampling and gaging unit was then installed at a 2-bedroom, 4 person house served by a 536-gallon concrete rectangular tank, 72 inches x 33 inches x 52 inches equipped with tee inlet and outlet facilities.

Daily volumes of flow are shown in Fig. 21 , and the results obtained for the four installations are summarized in Tables 25 and 26 . Chemical characteristics of the effluents are given in Table 27.



SURVEY No. 5-39

Nov 13 - 30 1947

SEWAGE AVE DAILY FLOW = 23.0 GAL. PER CAPITA.
WATER AVE DAILY FLOW = 25.1 GAL PER CAPITA

SURVEY No. 5-8

Oct 17 - Nov 11 1947

AVE. DAILY FLOW OF SEWAGE =
33.3 GAL PER CAPITA

WATER AVE DAILY FLOW =
42.7 GAL PER CAPITA

SURVEY No. 5-18

SEP 4 - 24 1947

PART A - BEFORE LEAKAGE SEALED
AVE. FLOW = 43.8 GAL PER CAP.

PART B - AFTER LEAKAGE SEALED
AVE. FLOW = 15.9 GAL PER CAPITA

A. AVE DAILY FLOW WATER = 34.8 GAL PER CAP.
B. AVE DAILY FLOW WATER = 23.0 GAL. PER CAP.

SURVEY No. 5-11

JULY 29 - AUG 12 1947

AVE DAILY FLOW OF SEWAGE 43.1 G/C
AVE DAILY FLOW OF WATER = 58.8 G/C

FIELD SAMPLING [illegible]
DAILY FLOW VARIATIONS
SEPTIC TANK EFFLUENT.

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FIG. 21

Table 25 Sampling & Gaging Data

Survey No.	Water Use						Sewage Flows								
	Gallons per day			Gal. per capita/day			Gallons per day			Gal. per capita/day			Theoretical Detention Time Days		
	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
5-11	235.4	499.0	101.8	58.8	124.7	25.4	168.0	225.9	95.0	42.0	60.0	31.3	5.32	9.40	3.95
5-18a(1)	102.8	138.0	76.4	34.3	46.0	25.5	131.5	196.0	95.1	43.8	65.3	31.7	6.11	7.28	3.84
b(2)	39.1	67.4	23.2	23.0	22.5	7.8	47.9	94.4	19.7	16.0	41.2	7.36	18.4	38.2	7.96
5-8(3)	128.1	206.9	47.8	42.7	68.6	15.9	99.9	356.2	9.36	33.3	118.7	3.12	7.18	76.5	2.01
5-39	75.4	180.0	29.6	25.1	60.0	9.8	96.6	261.8	28.2	24.2	66.2	7.06	5.55	19.0	2.05

* (1) Before correction of leakage
(2) After correction of leakage
(3) Water taken for construction purposes at start of survey.

Table 26 Sampling & Gaging Data

Survey No.	Period of Observation	No Bedrms.	No Persons	Sewage Flows per Day		
				Av.	Per Bdrm.	Per Cap.
5-11	July 29 - Aug. 12	3	4	168.0	56.0	42.0
5-18a(1)	Sept. 4-24	2	3	131.5	65.8	43.8
b(1)		2	3	47.9	24.0	16.0
5-8	Oct. 17 - Nov. 11	2	3	99.9	50.0	33.3
5-39	Nov. 18-30	2	4	96.6	48.3	24.2

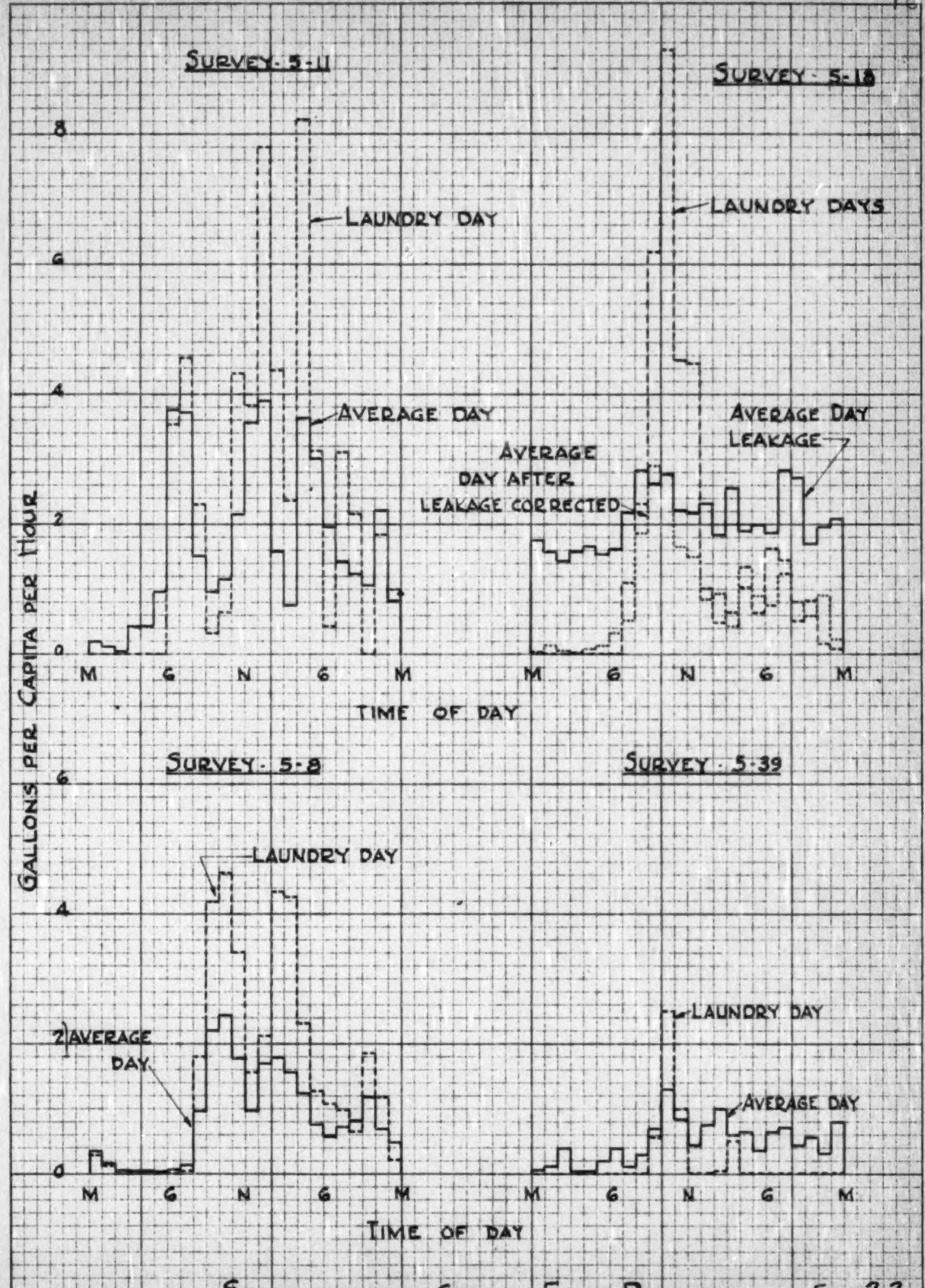
(1) See notations at bottom of previous table.

Table 27 - Chemical Data - Field Sampling & Gaging

Item	Survey Number				
	5-11	5-18		5-8	5-39
		a(1)	b(1)		
Total solids ppm.	792	876	1335	849	944
Total solids - volatile ppm.	455	427	704	533	655
Total solids - ash "	338	450	629	317	292
Suspended Solids "	97	154	215	128	189
" " volatile "	13	33	55	43	89
" " ash "	84	121	160	85	98
Dissolved solids "	692	722	1118	719	758
" " volatile "	440	393	651	487	556
" " ash "	252	329	468	230	196
Alkalinity - ppm.	394				
pH	7.4	7.3	7.4	7.6	7.6

(1) See previous table for significance of these notations
(2) Weighted average.

Average hourly variations in flow, as obtained from a study of the recorded charts, are illustrated in Fig. 22 . The average day data presented for surveys 5-8 and 5-39, have been corrected for rainfall drainage collected and discharged through a sump pump into the septic tank. It must be remembered that all sewage flow data presented herein on sampling and gaging were collected from the effluent end of the septic tank prior to entry into the tile field. Actual variations in flow, therefore, may be greater than those shown due to the damping effect caused by discharge through the septic tank. This effect would be particularly noticeable in a large tank.



SAMPLING AND GAGING - FLOW PATTERNS FIG-22

KEUFFEL & ESSER CO., N.Y. NO. 359-5
10 X 10 to the inch, 10th lines heavy.
MADE IN U.S.A.

Table 28 presents data showing comparisons between the average hourly and peak flows with those obtained on laundry days. The percent increase in average hourly laundry flow and peak flows based on the hourly average flow is also given.

Table 28 Hourly & Peak Flows - Normal & Laundry Days

Survey No.	Hourly Flows - gal/capita				Percentage Laundry based on hourly average	
	Sewage		Laundry			
	Average	Peak	Average	Peak	Average	Peak
5-11	1.67	3.87	2.26	8.22	135.0	492.2
5-18 (b)	0.87	2.87	1.51	9.29	173.8	1068.0
5-8	0.85*	2.43	1.51	4.61	177.6	542.0
5-39	0.72*	1.30	0.19	2.50	26.4	347.0

* Corrected for rainfall drainage through tank.

These data indicate that the laundry flow exceeds the sewage flow by approximately 75 percent, but that peak flows may be ten times higher than the average sewage flow. Sewage peak flows were found to be 3.3 times greater than the average flow.

None of these installations were equipped with automatic laundry units.

7. Conduct laboratory investigations on the soil-clogging characteristics of tank effluent.

Results of laboratory investigations of clogging characteristics of tank effluents to date are presented in Item 3 under Clogging Characteristics, page 61 and Bacteriological, page 66.

The bacteriologist assigned to the Project was released in January upon completion of the studies before mentioned, due to necessary reduction in forces.

A Public Health Service Research Grant-in-Aid project, "A Study of the Capacity of Soils for the Sub-Surface Disposal of Settled Sewage", to be undertaken by Dr. E. J. Kilcawley of Rensselaer Polytechnic Institute, is expected to get under way soon. Contact has been made with Dr. Kilcawley and a second conference will be held in Cincinnati February 13th to discuss coordination with the H.H.F.A.-U.S.P.H.S. project.

8. Study the economic and general feasibility of constructing systems with sufficient sludge capacities to require cleaning at only 10 or 20-year intervals.

Pending the development of sufficient data to indicate tank cleaning points and trends in efficiencies of solids removal, aside from other criteria of performance which may develop, some trial computations were made on the economics of various sizes of tanks, using the sludge and scum accumulation data assembled from field surveys and assuming that a residual settling capacity (total liquid capacity minus volume of accumulated sludge and scum) of 50 gallons per person was required at cleaning time. On this basis the indication was that for a four person installation the 500 gallon capacity rectangular tank gave lowest total annual costs with a cleaning frequency of about 7 years. A four person 600 gallon tank was slightly higher in annual cost with a 10 year frequency, and a 1000 gallon tank with a 20 year interval, about 30 per cent higher.

The above trial computations were made on a very limited basis and do not take into account other factors which should be considered when data are available, such as possible differences in the clogging characteristics of the effluent, the rate of change in efficiency, etc., with accumulation of sludge and scum in tanks of various sizes under the same person loading.

9. Study the effect of extreme freezing conditions on the functioning of a properly designed and constructed subsurface disposal field and determine what modifications should be incorporated in accepted design practices for cold climates.

The solicitation of plumbers in the northern part of the country for information concerning the effect of freezing weather on septic tank operation has been continued. Late in August, an additional 101 plumbers were contacted, making a total of 162. Of the total group, replies were received from 65, and, of these, 62 were suitable for reviewing. All replies have been used in preparing the discussion for this report.

The letter to the plumbers included the following questions.

1. What is the usual practice in installation with which you are familiar in your locality, as to the depth of the house sewer, the tank, and tile field?
2. Do you know of any tile fields 18" to 24" below the ground surface?
3. Do these shallow systems freeze if in constant use?
4. What part of the system freezes first; the sewer, the tank, or the tile field?
5. Are any special precautions taken, such as covering the tank and field with hay or manure, or other measures?
6. Are dosing siphons generally used?
7. Do you know of any cases where a shallow system installed in the Fall freezes the first Winter and operates satisfactorily after that? What about installations made in the Spring in this connection?
8. Are the lines of the absorption vented to the ground surface? Have you found any difference in operation, with respect to freezing circumstances between vented and unvented tile fields?

From the results of this survey it appears that the usual practice is to place the septic tank system approximately 1 to 3 feet below the ground surface. Only 9 plumbers stated that depths of 6ft. or greater were used, and the majority of these gave a range of depths with an earth cover as small as 2 ft.

One plumber in Houghton Lake, Michigan recommended keeping the systems from 6 to 12 in. below the ground surface to promote better operation.

Thirty-seven plumbers replied in the affirmative to Question 2 (knowledge of systems 18 to 24 inches below the ground surface), and, of these, only 3 replied that such systems froze when in constant use. Of this group, one plumber stated that his experience was limited, another that he knew of only one instance - a school, and the other stated that freezing occurred only when there was no snow cover. Another plumber stated that these systems did not freeze if there was snow cover.

In response to the question concerning the part of the system to freeze first, 10 plumbers replied that no freezing occurred. Answers varied quite widely for those giving the part of the system freezing first. The majority stated that the field would freeze first, however, all parts, as well as many combinations, were noted.

Of 49 replies received to the question concerning the insulation of the system during the Winter months, 23 replied that special precautions were taken. Most all replies were qualified somewhat. Some plumbers stated such precautions were carried out only occasionally, while others recommended protection. One plumber stated that a 12 in. cover of new straw was better than manure.

Only 4 plumbers replied that dosing siphons were generally used, and a few indicated that they were used only on large installations. Two plumbers stated that vented tile fields freeze more readily than unvented ones. Five plumbers indicated that some fields were vented, and only 4 stated that all tile fields were vented. One plumber stated that only large systems were vented, and that venting had no effect on freezing of the field.

Fifteen replies were received which indicated knowledge of freezing occurring during the first winter, in systems installed late in the Fall, and providing satisfactory service after that. The question was asked with the thought that a system, installed after warm weather and not seeded, would not have time to start septic action before the advent of cold weather. Thus, the heat of digestion would not be available to help prevent the freezing of the tank.

From the results of this survey of plumbers and the references cited in the First Progress Report, the following conclusions are indicated:

1. That septic tank systems in constant use and with relatively shallow earth cover do not readily freeze, particularly when snow cover exists. In regions where periods of extreme freezing without snow cover may prevail, special protection, such as straw cover, appears a wise precaution.
2. That shallow systems are in more general use in freezing climates that was thought, and that cases of freezing of these systems are infrequent.
3. That the use of dosing siphons is not necessary to prevent freezing.
4. That a septic tank installed late in the Fall should be properly seeded to initiate septic action as soon as possible, rather than to allow an accumulation of raw solids during the first Winter. Experience of 15 plumbers replying to the questionnaire indicated that freezing of systems installed under these conditions, and apparently not seeded, occurred the first Winter.

10. Study the effect of tree and shrubbery roots on disposal systems and the ability of roots to absorb significant portions of sewage effluent through all seasons of the year.

Further study of this topic is temporarily suspended due to personnel limitations.

11. Determine the effect of residential garbage grinding on septic tank operation and what modifications in design should be made to permit this service.

The review of literature on this subject was covered in the First Progress Report.

A 500 gallon Joint Committee tank receiving ground garbage from a family of two (originally three) in addition to a sewage load has been under observation at the Laboratory since August 19, 1947. As reported under Item 3 present results show removals equal to or greater than in the comparable 500 gallon Joint Committee tank receiving sewage only.

Efforts made to develop field inspections on several garbage grinder-septic tank equipped homes reported by General Electric representatives in the Cleveland area, through the assignment of a field team to the area for the purpose, were unproductive, because of inability to locate tanks, absentee owners, etc.

Further efforts will be made to obtain inspections in the field although it is evident from the field work thus far that such installations are difficult to find.

12. Test various distribution box installations as a basis for determining the most efficient design for these structures.

No direct study of distribution boxes has been undertaken as yet although a number of designs are at hand from various solicitations. It is expected that some experimental work on this will be undertaken in the Spring, to an extent dependent on pressure of other undertakings under present reduced personnel circumstances.

13. Investigate feasibility of changing the ratio of horizontal and vertical areas of septic tanks so as to permit a shorter detention period and increased sludge storage capacity.

Present experimental operation of the variety of tank shapes and sizes now set up should provide preliminary information in this connection. Of interest also is the possible benefit to introduction of incoming sewage through the sludge and, if found advantageous, the changes in design and maintenance necessary to realize such benefit. Small scale laboratory studies on the effects of introduction of sewage through the sludge are being undertaken in this connection. The determination of actual detention periods will be undertaken when personnel circumstances permit.

14. Study the discharge of normal amounts of grease directly into a septic tank of adequate size and determine the effect of grease on septic action and on the efficiency of septic tank systems.

High removals, ranging from 72.4 to 92.4 per cent were indicated in laboratory determinations made of grease contents of the raw sewage and effluents of various tanks now in operation at the Laboratory, leading to the thought that grease traps between house and septic tank are not necessary. Further work with increased grease loadings is contemplated following completion of present parallel operation of tanks as a battery for comparative purposes.

15. Determine the relation of Sodium and Calcium to the soil-clogging action of the effluent.

Study of this item has been deferred pending the guidance of a soils scientist, as it is felt that considerable information will be available from the agricultural field. Contacts with soils scientists attending a national meeting of agronomists at Cincinnati some time ago left the impression that high sodium to calcium ratio waters can very effectively reduce drainage characteristics through exchange and deflocculation, and moreover that ammonia and sulfur compounds also may affect drainage characteristics through such soil dispersion.

16. Investigate the relationship of (a) seepage, lateral or vertical (b) evaporation and (c) transpiration to the overall efficiency of a subsurface disposal system.

The status of this topic is essentially the same as reported previously. Completion of the review of literature on the subject previously carried on part time by a member of the Cincinnati Station Staff until other duties intervened, and the undertaking of further work pends availability of personnel for the assignment. The work to be undertaken under the research grant-in-aid project at Rensselaer, previously mentioned (Topic 7, page 80), will no doubt contribute to the knowledge on at least one part of this topic.

17. Study and investigate new methods of disposal, particularly substitute methods for subsurface disposal.

Efforts thus far have been concentrated on developing a factual foundation and knowledge of the status of present methods, in connection with which it is expected that improvements will logically follow. However no new methods of disposal of general applicability have been uncovered to date.

18. Develop recommended minimum standards of design for septic tank systems.

The review of past work and knowledge in the household sewage disposal field has shown that the structure has little factual support and much dogma, perpetuated through borrowing and repetition, and that there is great need for basic work.

It should be evident from the two progress reports that an attack on many of the basic problems is being made, but also that much work remains to be done before the ultimate objective of standards of design, and possibly performance, based on facts can be reached.

Many improvements to present practice could no doubt be realized from trends now being developed on an experimental basis, although their direct application, without confirming field trial would be speculative. Thus, although scientific propriety demands conservative treatment of experimental data, it is felt that considerable direct progress has been made toward the major objective at this time.

Consideration of future work should include, in addition to continued attack on basic problems, with particular stress on absorption system problems, a program of intensive field sampling and gaging, to bear out experimental findings and to furnish knowledge on normal variation in different households in quantity and character of wastes to aid in the effort to set up performance, as well as design standards. Considerable field work over a relatively long period of time will be necessary to bear out the experimental absorption field studies abovementioned.

APPENDIX A

LITERATURE SURVEY AND BIBLIOGRAPHY

Table 14. HOUSE SEWER - SUMMARY OF STATE

No.	State	Min. Diam.	Min. Grade ft/100'	Type	Joints
1	Alabama	6"	0.5	V.C.(B&S)	Tight cement
2	Arizona				
3	Arkansas	4"	1.0	V.C.(B&S) or impervious mat'l.	Cement mortar, or approved filler
4	California		1.0		
5	Colorado	4"		V.C.(B&S)	
6	Connecticut	4"	1.0		
7	Delaware	4"		C.I. or V.C.(B&S)	Tightly jointed
8	Florida	4"	0.5	C.I. soil pipe	Leaded joints
9	Georgia	4"	1.5	V.C.(B&S)	Special jointing compounds
10	Idaho	Adequate	1.0	V.C., Conc. or C.I.(B&S)	
11	Illinois	4"	2.0	V.C.(B&S)	Cemented joints
12	Indiana	6"	2.0	V.C.(B&S)	Mortar or approved joint compound
13	Iowa	4"	1.0	V.C.(B&S)	Cement mortar or patented joint filler
14	Kansas	4" C.I. 6" V.C.	1.0	B&S	Watertight & protect from roots.
15	Kentucky	4"		V.C.(B&S)	Cemented
16	Louisiana	4"		C.I.,V.C.(B&S) or other appr. mat'l.	Bituminous or cement joints.
17	Maine				
18	Maryland	5"	0.65	V.C. or C.I.(B&S)	Cement or lead
19	Massachusetts				
20	Michigan	4"	1.0	V.C.(B&S)	Mortar, asphaltic or bituminous
21	Minnesota	4"C.I. 6"V.C.	2.0 1.0	V.C. or C.I.(B&S) or accpt. mat'l.	Mortar or lead
22	Mississippi				
23	Missouri	6"	1.0	V.C.(B&S)	Bitumen or cement
24	Montana				
25	Nebraska				
26	Nevada				
27	New Hampshire		1.3		
28	New Jersey				
29	New Mexico				
30	New York	6"	1.0	V.C.(B&S)	Tar or cement

WER - SUMMARY OF STATE REQUIREMENTS

s	Remarks
	Sealed joint C.I. pipe within 50' of water supply.
or approved	Recommend 6" sewer, .66'/100' caulked lead joint C.I. pipe within 100' of water supply. "A good root-tight sewer"
d	
ng compounds	C.I. pipe for filled ground, or other special condition.
oved joint compound	C.I. pipe within 50' of wells.
or patented joint fillers	C.I. pipe within 50' of wells.
otect from roots.	
ement joints.	
ic or bituminous	C.I. pipe within 50' of well.
	C.I. pipe in loose texture, fissured & limestone areas, within 50' of well.
nt	C.I. pipe within 50' of well.
	C.I. pipe within 100' of well.
	C.I. pipe within 50' of well.

19	Massachusetts				
20	Michigan	4"	1.0	V.C.(B&S)	Mortar, asphaltic or bituminous
21	Minnesota	4"C.I. 6"V.C.	2.0 1.0	V.C. or C.I.(B&S) or accpt. mat'l.	Mortar or lead
22	Mississippi				
23	Missouri	6"	1.0	V.C.(B&S)	Bitumen or cement
24	Montana				
25	Nebraska				
26	Nevada				
27	New Hampshire		1.3		
28	New Jersey				
29	New Mexico				
30	New York	6"	1.0	V.C.(B&S)	Tar or cement
31	North Carolina				
32	North Dakota	4"C.I. 6"V.C.	2.0 1.0	V.C. or C.I. (B&S)	Mortar or lead; hot poured near trees and shrubs
33	Ohio	4"	1.0	C.I.(B&S)	Lead
34	Oklahoma	6"	1.0	V.C.(B&S)	Mortar (Water tight)
35	Oregon	4"	2.0	C.I.,V.C., cem. asb. bit. fibre, (B&S)	Watertight lead, mortar or bituminous
36	Pennsylvania	6"		V.C.(B&S)	Cemented
37	Rhode Island				
38	South Carolina	4"	2.0	C.I. or V.C. (B&S)	
39	South Dakota	6"	1.0	V.C.(B&S)	Bitumen or cement
40	Tennessee				
41	Texas	4"	[illegible]	V.C.(B&S)	Tight joint
42	Utah		2.0	V.C. or C.I.(B&S)	Cement, bitumen
43	Vermont	6"	0.7	V.C.(B&S)	Mortar or bituminous compound
44	Virginia	4"	1.7	V.C. or Concrete (B&S)	Mortar
45	Washington				Tight joints
46	West Virginia	6"	1.0	V.C.(B&S)	Mortar
47	Wisconsin			V.C. or C.I.	
48	Wyoming				

ment joints.	
ic or bituminous	C.I. pipe within 50' of well.
	C.I. pipe in loose texture, fissured & limestone areas, within 50' of well.
ot	C.I. pipe within 50' of well.
	C.I. pipe within 100' of well.
	C.I. pipe within 50' of well.
hot poured near trees	C.I. pipe within 50' of well & in loose texture fissured limestone, lignite & scoria formations.
ght)	
mortar or bituminous	C.I. pipe within 50' of well.
t	C.I. pipe within 50' of well
nous compound	C.I. pipe within 100' of well (Min. size = 4")
	C.I. pipe within 50' of well
	C.I. pipe within 50' of well
	C.I. pipe within 100' of well. Suggest use of sulphur base compound & copper rings to prevent root entrance.
	C.I. pipe within 25' of well

TABLE 2A

No.	State	Approved	Size	Absorption Area Percolation Test-sq.ft./bdrm. Minutes 1	2	3	4	5	10	15	30	45	60	Coarse sand or gravel	Fin or loa
1	Alabama	No													
2	Arizona														
3	Arkansas	Yes	6' deep(max)-4' diam. or square												
4	California	Yes													
5	Colorado	Yes	6' dia.-dug 3' in coarse sand or gravel												
6	Connecticut	Yes			34	40	46	50	66	80	126	174	220	39	6
7	Deleware	Yes	10'-12' deep below inlet												
8	Florida	No													
9	Georgia	-													
10	Idaho	Yes	4' dia. into 4' of porous formation.											20	3
11	Illinois	Yes	2'-5' dia.												
12	Indiana	Yes	Not over 10' deep												
13	Iowa	-													
14	Kansas	-													
15	Kentucky	-													
16	Louisiana	Yes													
17	Maine	Yes													
18	Maryland	Yes	5' dia.-about 12' deep	31	39			47	71		102		US		
19	Massachusetts	-													
20	Michigan	Yes	5'-6' dia.;5' below inlet												
21	Minnesota	Yes													
22	Mississippi	-													
23	Missouri	Yes													
24	Montana	-													
25	Nebraska	No													
26	Nevada	-													
27	New Hampshire	Yes		20	24			34	46		100	US		6	
28	New Jersey	Yes													

TABLE 2A. SEEPAGE PITS– SUMMARY OF STATE REQUIREMENTS

Absorption Area													
.ft./bdrm.				sq.ft./bdrm.					Location - Feet				
15	30	45	60	Coarse sand or gravel	Fine sand or sandy loam	Sand or loam, some clay	Clay, some sand or gravel	Clay	Any water supply	Streams	Dwgs.	Prop. Lines	
									100	100			Pit recommende
									250		25	25	Install tile fi water table, w
									300	100			
80	126	174	220	39	64	128			50				Allow 3 dia.
													Open joint, st
													"Sumps, dry we used for dispo
				20	30	50	80-160	US	100		20	10	"Necessary with table.
									100				Allowed with o stone.
									75	25	50	5	Not approved u is used; disapp Inadvisable as
									50				
									100	60			
	102		US						50				For septic tan bottom. Not us
									50				Health dept. a soil. Use of abandone Pits to be at
													"Tile fields a
													"In no case is pool", for an
	100	US		6	9	15	24	US	100	75			Not suitable least 2'

STATE REQUIREMENTS

Clay	Location - Feet Any water supply	Streams	Dwgs.	Prop. Lines	Remarks
	100	100			Pit recommended at end of tile line or filter.
	250		25	25	Install tile field and/or seepage pit depending on soil, water table, wells & lot space.
	300	100			
	50				Allow 3 dia. space between pits.
					Open joint, stone or brick.
					"Sumps, dry wells, soakage pits or drain wells shall not be used for disposal of septic tank effluent".
US	100		20	10	"Necessary with cesspools". No pits to be dug into water table.
	100				Allowed with or without tile field; lined with brick or stone.
	75	25	50	5	Not approved unless tile fields fail or public water supply is used; disapproved near shallow wells.
					Inadvisable as means of septic tank effluent disposal.
	50				
	100	60			
	50				For septic tank effluent. Brick lined abs. area to exclude bottom. Not used in shallow well areas.
	50				Health dept. approval required. Should extend to porous soil. Use of abandoned well, cesspool, sinkhole, etc. not allowed. Pits to be at least 10' above water table.
					"Tile fields are more satisfactory than leaching cesspools".
					"In no case is it advisable to use a leaching well or cesspool", for an absorption field.
US	100	75			Not suitable if water table within 8' of surface; bottom at least 2' above water table. gcd flow = 30 gal.

			below inlet								
21	Minnesota	Yes									
22	Mississippi	-									
23	Missouri	Yes									
24	Montana	-									
25	Nebraska	No									
26	Nevada	-									
27	New Hampshire	Yes		20	24	34	46	100	US	6	9
28	New Jersey	Yes									
29	New Mexico	Yes									
30	New York	Yes	6' dia.	32	40	56	76	160	US	20	30
31	North Carolina	Yes	3' dia. 3' deep								
32	North Dakota	Yes									
33	Ohio	Yes	Cap=675 gal. or = septic tank cap.								
34	Oklahoma	-									
35	Oregon	Yes	4' dia. cap.=septic tank							20	30
36	Pennsylvania	-									
37	Rhode Island	-									
38	South Carolina	-									
39	South Dakota	Yes									
40	Tennessee	-									
41	Texas	-									
42	Utah	No									
43	Vermont	Yes	Cap.= septic tank								
44	Virginia	-									
45	Washington	Yes	3' dia. & 3' deep								
46	West Virginia	Yes	4' sq; variable depth.								
47	Wisconsin	Yes	6' or more below inlet pipe								
48	Wyoming	Yes	6' dia. 3' into porous formation								

											Use of aband
											Pits to be at
											"Tile fields
											"In no case i
											pool", for an
100	US	6	9	15	24	US	100	75			Not suitable
											least 2' abov
							50				"A pit at lea
											dug at the end
160	US	20	30	44	US		100				For daily p.c.
											suitable if wa
							50				Should be dug
							50				If possible si
											used in favora
							100				Not for less t
											gravel above w
		20	30	50	80-160	US	150	25	10	10	Health dept. a
											well areas. Fo
											Operate satisf
							100		20		Allowed "under
											on bottom - bo
											"A pit---should
											Filled to surf
							100				Consult health
							150		50		
											Use after sept

				Use of abandoned well, cesspool, sinkhole, etc. not allowed. Pits to be at least 10' above water table.
				"Tile fields are more satisfactory than leaching cesspools".
				"In no case is it advisable to use a leaching well or cesspool", for an absorption field.
100	75			Not suitable if water table within 8' of surface; bottom at least 2' above water table. gcd flow = 30 gal.
50				"A pit at least 3' in dia. by 1 to 3 feet deep should be dug at the end of the tile line." Filled with cinders.
100				For daily p.c. flow = 50 gal.-Excludes bottom area. Not suitable if water table is less than 8' deep.
50				Should be dug at end of tile line.
50				If possible situate at least 10' above water table, can be used in favorable soils without tile field.
100				Not for less than ½ acre lots. Sides & bottom in sand or gravel above water table.
150	25	10	10	Health dept. approval req., not used in limestone or shallow well areas. For daily p.c. flow = 50 gal.
				Operate satisfactorily in relatively porous soil.
100		20		Allowed "under favorable ground conditions". 1' of gravel on bottom - bottom 2' above water table.
				"A pit---should be dug at the end of the tile line." Filled to surface with cinders.
100				Consult health dept. installed at end of tile not lined.
150		50		
				Use after septic tank or at end of tile line.

Table 3A. CESSPOOLS - SUMMARY OF STAT

No.	State	Approved	Re
1	Alabama	No	"Cesspools, leaching pools and the like are st
2	Arizona	-	
3	Arkansas	-	
4	California	Yes	Ground water should be 15' to 20' below the su
5	Colorado	-	
6	Connecticut	Yes	No cesspools within 50' of a water supply stre
7	Delaware	-	
8	Florida	-	
9	Georgia	-	
10	Idaho	Yes	Acceptable only in certain areas, not al
11	Illinois	Yes	Allowed in very porous soils, 100' from wells.
12	Indiana	No	
13	Iowa	Yes	Allowed for kitchen and laundry wastes - No st
14	Kansas	No	Cesspools have been condemned, also the use of
15	Kentucky	-	
16	Louisiana	Yes	Local health dep't. approval required: Not to
17	Maine	Yes	Health dep't. approval required: not allowed
18	Maryland	-	
19	Massachusetts	-	
20	Michigan	No	
21	Minnesota	No	"A cesspool is not recommended as a substitute
22	Mississippi	-	
23	Missouri	-	
24	Montana	-	
25	Nebraska	-	
26	Nevada	-	
27	New Hampshire	-	
28	New Jersey	Yes	5' - 10' diam. and 7' - 12' deep; brick or ston
29	New Mexico	-	
30	New York	Yes	Preferably follow a septic tank or built in 2

SSPOOLS - SUMMARY OF STATE REQUIREMENTS

Remarks

pools and the like are strongly disapproved---."

be 15' to 20' below the surface, if used.

50' of a water supply stream. Recommend septic tanks.

ertain areas, not allowed in shallow well areas - min. cap. 1000 gal., 3' dia.

ous soils, 100' from wells. Lined with brick or stone.

and laundry wastes - No statement re sewage - Max. depth 12' 1½ to 3 c.y. cap. (crushed stone fill).

condemned, also the use of abandoned wells.

approval required: Not to be used where ground water supply will be contaminated.

al required: not allowed if water table is less than 4' deep. Use of abandoned wells not allowed.

ecommended as a substitute for a settling tank."

- 12' deep; brick or stone lined - Not allowed around shallow wells.

eptic tank or built in 2 units, 6' diam; bottom above water table: stone, brick or building tile lining.

22	Mississippi	-	
23	Missouri	-	
24	Montana	-	
25	Nebraska	-	
26	Nevada	-	
27	New Hampshire	-	
28	New Jersey	Yes	5' - 10' diam. and 7' - 12' deep; brick or stone li
29	New Mexico	-	
30	New York	Yes	Preferably follow a septic tank or built in 2 unit
31	North Carolina	-	
32	North Dakota	No	
33	Ohio	-	
34	Oklahoma	-	Apparently not allowed.
35	Oregon	Yes	Local hlth. dept. approval reqd. - 4' min. dia. & seepage pits.
36	Pennsylvania	-	
37	Rhode Island	-	
38	South Carolina	-	
39	South Dakota	-	
40	Tennessee	-	
41	Texas	-	
42	Utah	Yes	For disposing of floor waste only. Only a tempor water table.
43	Vermont	Yes	For laundry wastes. Not recommended for sewage.
44	Virginia	-	
45	Washington	-	
46	West Virginia	-	
47	Wisconsin	No	Cesspools are contrary to the code.
48	Wyoming	-	

12' deep; brick or stone lined - Not allowed around shallow wells.

ptic tank or built in 2 units, 6' diam; bottom above water table: stone, brick or building tile lining.

.

oval reqd. - 4' min. dia. & 15' below inlet, penetrate 5' into porous material - location same as

waste only. Only a temporary expedient for sewage. 5' diam. lined with cobble stone and above

ot recommended for sewage.

to the code.

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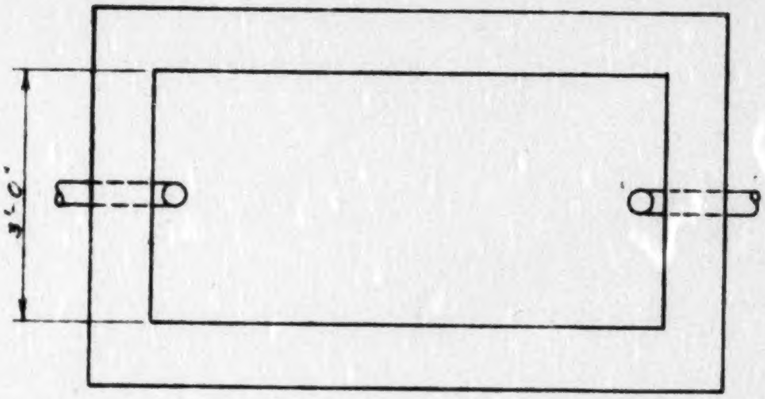
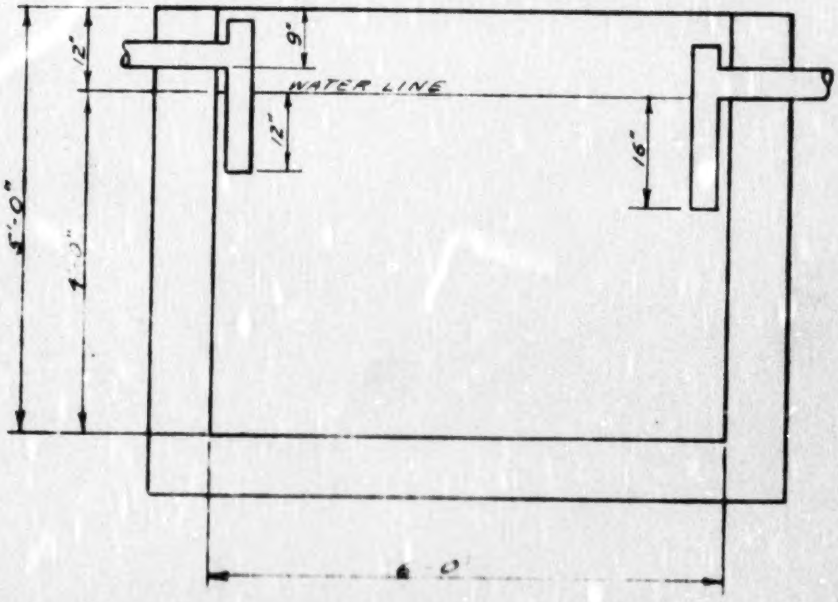
APPENDIX F

DRAWINGS OF EXPERIMENTAL SEPTIC TANKS

9. TANK J_G - JT. COMM. - GARBAGE
10 TANK X_L - JT. COMM - CONTROL, WEIR
15. TANK J_R - JT. COMM. - CONTROL, COMPARTMENTS

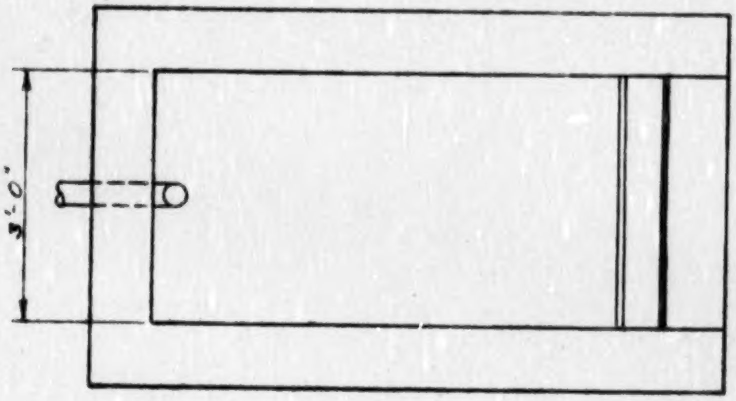


PLAN

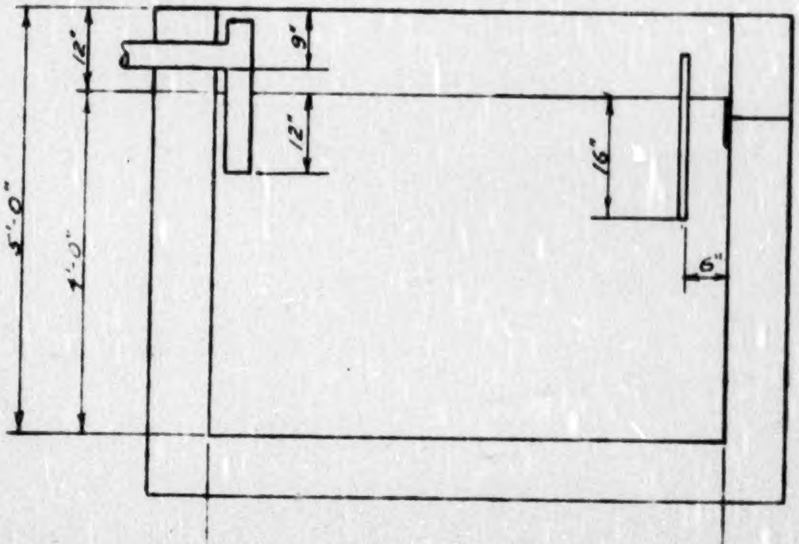

12"
9"
WATER LINE
12"
16"
5'-0"
4'-0"
6'-0"

SECTION

11. TANK X_2 - JT. COMM. - WEIR OUTLET



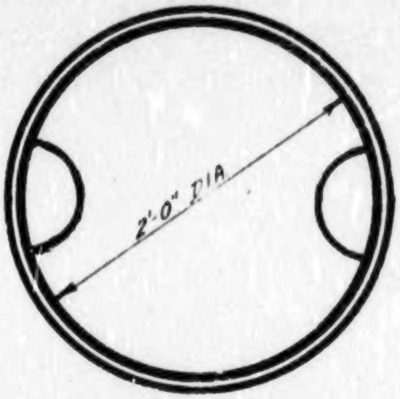
PLAN


12"
9"
12"
5'-0"
4'-0"
16"
6"
6'-0"

SECTION

12. TANK C_1 - TILE, SMALL - SINGLE STACK

13 TANK C_2 - TILE, SMALL - DOUBLE STACK, SERIES



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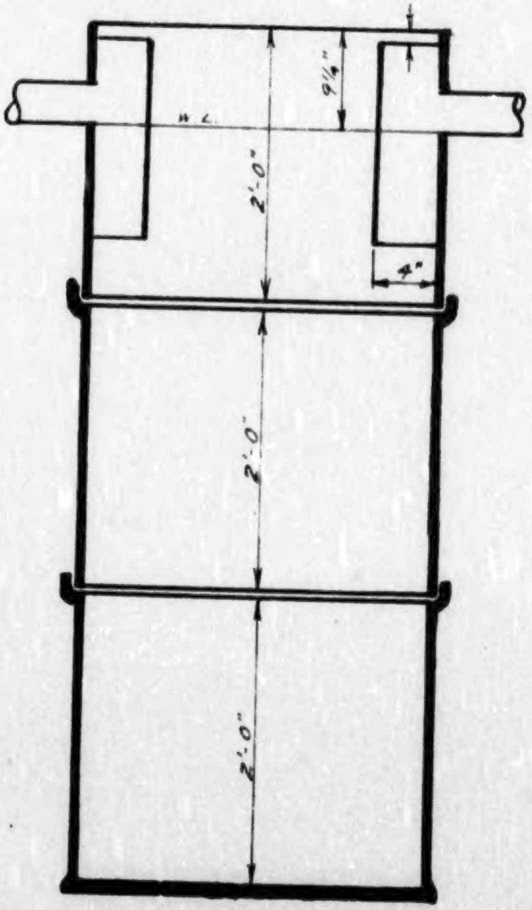
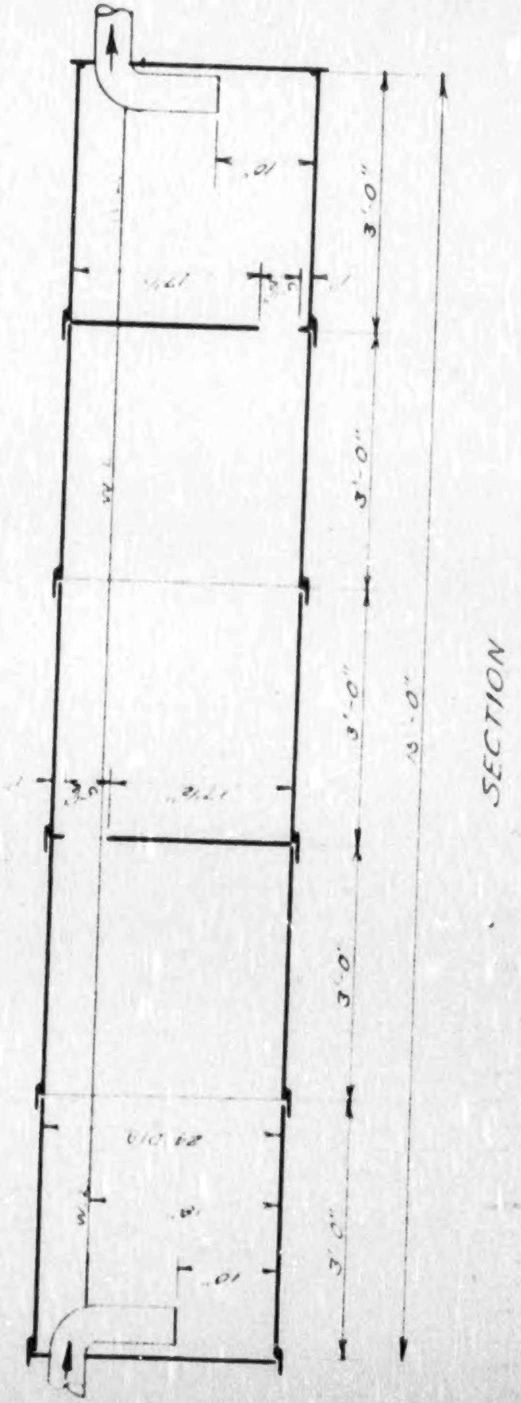
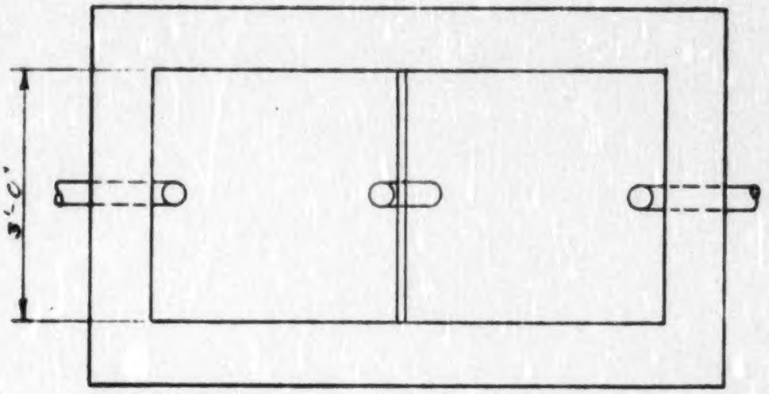

1"
9¼"
W.L.
2'-0"
4"
2'-0"
2'-0"

SECTION

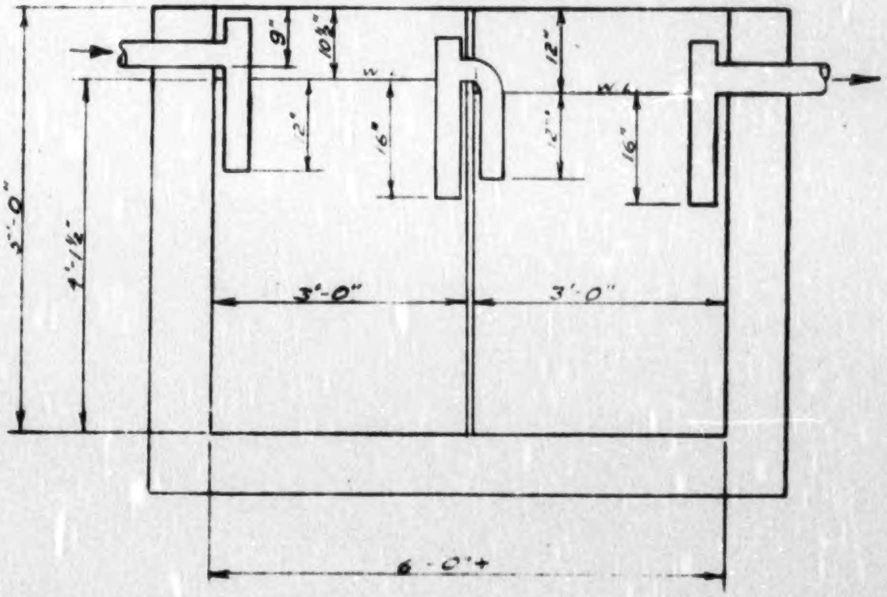
14. TANK D - TILE - HORIZONTAL 3 COMPARTMENT


SECTION
15'-0"
3'-0"
3'-0"
3'-0"
3'-0"
3'-0"
10"
12"
3"
12"
3"
10"

16 TANK J_2 - JT COMM. 2 COMPARTMENTS

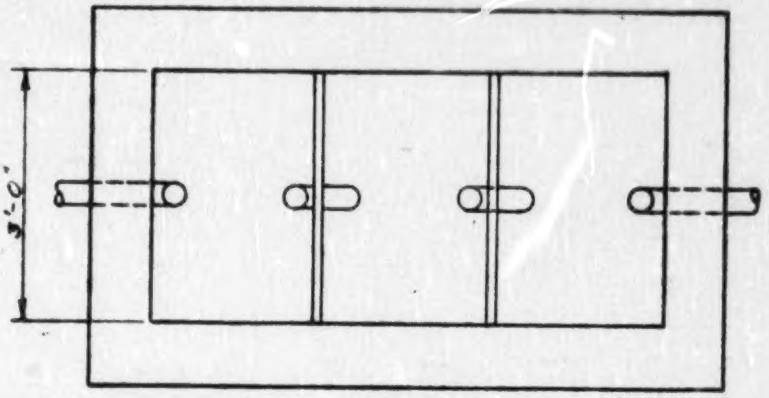


PLAN

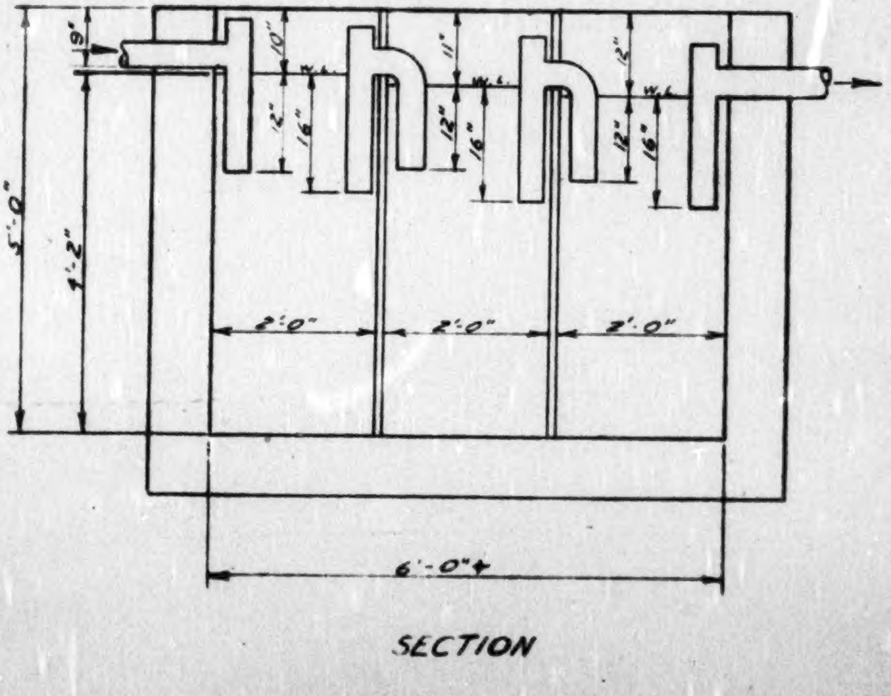

9"
10½"
W.
12"
2"
16"
12"
W.L.
16"
2'-0"
1'-1½"
3'-0"
3'-0"
6'-0"+

SECTION

17. TANK J_3 - JT. COMM. - 3 COMPARTMENT

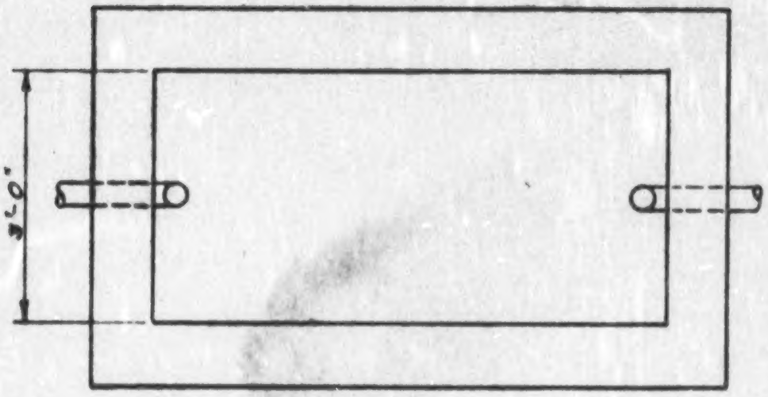


PLAN

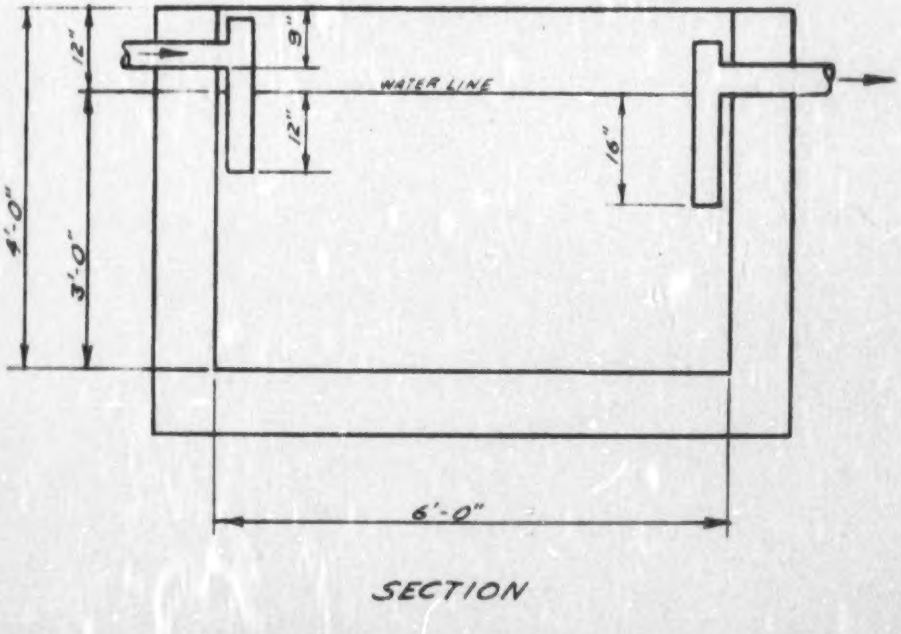

9"
10"
11"
12"
W.L.
W.L.
W.L.
12"
16"
12"
16"
12"
16"
5'-0"
4'-2"
2'-0"
2'-0"
2'-0"
6'-0"+

SECTION

18. TANK J_4 - JT. COMM. - 3 FT. WATER DEPTH



PLAN


12"
9"
WATER LINE
12"
16"
4'-0"
3'-0"
6'-0"

SECTION

APPENDIX G

RESEARCH AND LABORATORY FORMS

Date ________________
Sample ________________

U.S. Public Health Service
Cincinnati 2, Ohio

Septic Tank Study

Sampling Time													
Bottle No.													Composite
Temperature - Air													
Temperature - Liquid													
Volume Added													
Effluent Depth													
Effluent Gallons													
Color Effluent													
Total Solids													
Ash													
Volatile													
Suspended Solids													
Ash													
Volatile													
Dissolved Solids													
Ash													
Volatile													
pH													

Remarks: ________________

U. S. Public Health Service

Date ____________

TIME OF FLOW

Tank	7:00 A.M.			9:00 A.M.			11:00 A.M.			1:30 P.M.		
	Start	Stop	Diff.	ST	SP	DI	ST	SP	DI	ST	SP	DI
1												
2												
3												
4												
5												
6												
7												
8												

Tank	4:30 P.M.			7:00 P.M.			9:00 P.M.			10:30 P.M.		
	Start	Stop	Diff.	ST	SP	DI	ST	SP	DI	ST	SP	DI
1												
2												
3												
4												
5												
6												
7												
8												

STP Form No. 202 7/3/47

STP Form No. 101 7/ 47

U: S; Public [illegible]lth Service

PHYSICAL TEST - CONSTANTS OF SOILS

Date: ____________________
SP. GR. ____________________

Area: ____________________
Sample No.: ____________________
Depth: ____________________

LIQUID LIMIT DETERMINATION

Determination No.	1.	2.	3.	4.
Watch Glass No.				
Wt. of Watch Glass ∔ Wet Soil				
Wt. of Watch Glass ∔ Dry Soil				
Moisture Loss				
Wt. of Watch Glass				
Wt. of Dry Soil				
Moisture Content				
No. Blows	38	15		
Liquid Limit from Graph =				

PLASTIC LIMIT DETERMINATION

Determination No.	1.	2.
Watch Glass No.		
Wt. of Watch Glass ∔ Wet Soil		
Wt. of Watch Glass ∔ Dry Soil		
Moisture Loss		
Wt. of Watch Glass		
Wt. of Dry Soil		
Plastic Limit %		
Average Plastic Limit		

FORMULAS

1. V_c = Vol. Dry Soil Pat = $\frac{\text{Wt. Hg.}}{\text{Density Hg.}}$

WATER CONTENT

SITE	HOLE NUMBER	DEPTH

Sample identification and remarks

1. Watch Glass No.

Wet wt. sample ∔ glasses ________ gm.

Dry wt. sample ∔ glasses ________ gm.

Dry wt. sample ∔ glasses ________ gm.

Weight of glasses ________ gm.

Weight of water, W_w ________ gm.

Weight of solids, W_s ________ gm.

$W = \frac{W_w}{W_s}$ = ________ = ________ %

FINAL	RESULTS
LIQUID LIMIT =	
PLASTIC LIMIT =	
PLASTICITY INDEX	
WATER CONTENT	

Tester: ____________________
Computer: ____________________

SPECIFIC
GRAVITY

U. S. Public Health Service

SOILS LABORATORY

Area ______________

Sample No. ________

Depth ____________

Bottle No..............

Dish No..............

Weight bottle ≠ water ≠ sample, W_2 ______________ gm. __________

Weight of dry sample and dish ______________ gm. @ oC

Weight of dish ______________ gm.

Dry weight of sample, W_o ______________ gm.

Weight of bottle ≠ water, W_1 ______________ gm. @ ________ oC

$W_1 + W_o$ ______________ gm.

W_2 ______________

$W_1 + W_o - W_2$ ______________ gm.

$$s = \frac{W_o}{W_1 + W_o - W_2}$$

s = ...

Description of material:

Tester ____________________ Date ____________

Computer ____________________ Date ____________

STP Form No. 102 7/3/47

U. S. Public Health Service
Septic Tank Project
SIEVE ANALYSIS

Area
Sample #
Depth

Classification:

Sieve alone- -
Combined - - -

Screen Mesh/in.	Weight retained, grams	% Retained Sieve	% Retained Combined	% Finer Sieve	% Finer Combined	Diam. in mm.	Mesh in.
A						2 inches	A
B						26.67mm.	B
C						18.85mm.	C
D						13.35mm.	D
E						9.423	E
3						6.680	3
4						4.699	4
6						3.327	6
8						2.362	8
10						1.651	10
14						1.168	14
20						0.833	20
28						0.589	28
35						0.417	35
48						0.295	48
65						0.208	65
100						0.147	100
150						0.104	150
200						0.074	200
250						0.061	250
Pan							Pan

Total ________gm. Initial wt.__________gm. Tester________Date________

Hyd.wt. ________gm. Average wt.__________gm. Computer______Date________

Combined wt. ________gm.

STP Form No. 104 7/3/47

U. S. Public Health Service

HYDROMETER ANALYSIS

Area:

Sample #:

Depth:

Hydrometer:

Combined:

Color:

Visual Classif.:

Date	Time	Elapsed Time	R'	R	Temp. °C	Diameter in mm.	$R \neq M$	% Finer	Hydrometer No.
		MIN. 0							
		1/4							
		1/2							
		1							
		2							
		7							
		15							
		30							
		Hrs.							

$$W\% = \frac{s}{s - 1} \times \frac{100}{W_o} (R \neq M)$$

Tester:

Date:

Computer:

Date:

Hydrometer No.:

Dry weight, samp. & dish:

Weight of dish:

Dry weight, W_o, Hyd. alone:

Sieve Weight, Ave.

Combined weight:

STP Form No. 103 7/3/47